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ORIGINAL ARTICLES

INVESTIGATIONS ON THE RED LEAF DISEASE IN AMERICAN COTTONS*

I. RED LEAF DISEASE IN SIND-AMERICAN COTTONS IN SIND

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(Received for publication on 10th December 1946)

THE reddening of leaves in American cottons has been reported to occur ever since this type of cotton was introduced in India. Burt and Haider [1919] reported this phenomenon in Cawnpore-American cottons in the United Provinces, and later the same 'disease' was reported by Kottur [1920] from Dharwar and by Prayag [1927-28] from Khandesh. The reddening of leaves was also found to occur in the Punjab during the years when cotton crop failed in that Province [Milne, 1921 and 1922]. It was found to be present by Sawhney [1932] in Deccan Hyderabad. The red leaf 'disease' was also of common occurrence in Sind [Dabral, 1938]. It was also found to occur in the American Upland cottons grown in Central India [Rao and Wad, 1936]. Thus it was a 'disease' appearing in all parts of India where American cottons were grown.

As the red leaf in *hirsutum* cottons has been reported to occur under different conditions of soil and climate, it is possible that the causes that give rise to this common symptom in the leaves may be different. The leaves of *hirsutum* cottons have a tendency to redden whenever they become senescent either prematurely or at the end of the life cycle. It was, therefore, necessary to determine the different conditions under which this 'disease', as it is generally called, occurs.

The red pigment in the leaves of *hirsutum* cottons is also found to develop as a result of injury caused by Jassids [Sawhney, 1932]. The injury causes the death of leaf tissues and the red pigment subsequently develops. This investigation describes the red leaf that occurs in the absence of Jassid injury.

Rao and Wad [1936] have concluded that this 'disease' was caused by the bad soil conditions during the monsoon period in Malwa tract. They have also reported a higher osmotic pressure of the soil solution surrounding the diseased plants as compared with the osmotic pressure of the soil solution surrounding the healthy plants. Numerous determinations of the soluble solids in the soils from near the 'diseased' and healthy plants during this investigation revealed no differences that could account for such wide differences in the osmotic pressure.

Dabral [1938] had differentiated the red leaf 'disease' into different types of which one was caused by a deficiency of nitrogen and this was cured by the application of various fertilizers containing nitrogen. It will be shown below that yellowing and not reddening was a symptom of nitrogen deficiency, and that reddening was an after-effect that followed yellowing. In many cases reddening after yellowing did not occur. It has already been shown [Dastur, 1939 and 1941] that yellowing of leaves that occurred in the Punjab-American cottons in the Punjab was caused by a deficiency of nitrogen in light sandy soils where the development of the red pigment was not found to be of general occurrence.

INVESTIGATION

The red leaf 'disease' has been investigated in two tracts: (1) Sind and (2) Central India, where the soil and climatic conditions were quite different. The results so far obtained in Sind have been summarized below. It may be stated here that the work on the red leaf disease in American Uplands under rain-fed conditions in the Central India is at present in progress.

The most important American cotton growing tract is situated in the lower part of Sind where the acreage under American cotton is nearly 75 per cent of the total acreage of cotton in the province. This region includes the Tharparkar district and the southern part of the Hyderabad district. American cotton is also grown in the upper part of Hyderabad district and in Nawabshah district.

* This investigation was financed jointly by the Indian Central Cotton Committee and Sind Government

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on the Left Bank of the Indus river. Very small areas are under American cottons on the Right Bank in Dadu and Larkana districts.

The yellow-red leaf disease in Sind-American cottons mainly occurs in south Sind which is the most important cotton tract in Sind. This trouble appeared to be more frequent and widespread in this tract than in any other tract. In fact it was found to be present every season.

The previous findings of Dabral [1938] were based on the work done at Sakrand which is situated in Nawabshah district in middle Sind where the red leaf is neither acute nor so widespread. It was, therefore, considered necessary to conduct the investigations in Tharparkar and Hyderabad districts where this 'disease' was of common occurrence. The climatic conditions in south Sind are known to be different from the climatic conditions prevailing in middle Sind and it therefore appeared likely that this difference in the climatic conditions may be associated with the more widespread and a common occurence of the ' disease ' in the former tract.

Observations made on the cotton crop in Sind during the cotton season of 1942-43 showed that the reddening occurred in two ways and this difference has been, on further investigation, found to be of such great importance that the red leaf has been classified into two main types. In one type the change in colour of the leaf from green to red takes place through the intervening stage of yellowing. The leaves first turn pale and yellow before the red pigment develops. In this type of reddening, the leaves sometimes turn deep red or scarlet in colour. In the second type the change in colour from green to red occurs without the intervening stage of yellowing. The leaves in such cases urn bronze or copper coloured. The two types can be distinguished from a distance. Both the types have been found to occur in the different parts of the same block of land in Sind.

The analysis of the soil samples taken from the spots where these two types of red leaf occurred revealed important differences in their physical properties (Table I).

TABLE I

Mechanical analysis of the soil under yellow-red and green-red Sind American cottons

Depth in feet	Yellow-red			Depth in feet	Green-red		
	Clay per cent	Silt per cent	Sand per cent		Clay per cent	Silt per cent	Sand per cent
1st foot . . .	7	14	76	1st foot . . .	24	30	46
2nd foot . . .	11	17	72	2nd foot . . .	37	32	31
3rd foot . . .	9	26	64	3rd foot . . .	43	40	17
4th foot . . .	9	34	56	4th foot . . .	45	45	10
5th foot . . .	15	39	45	5th foot . . .	48	46	6
6th foot . . .	23	54	42	6th foot . . .	48	44	8

The soil under yellow-red type was light sandy containing a very high percentage of sand and low percentage of clay while the soil under green-red type was heavy containing low percentage of sand and high percentage of clay.

The physical texture of Sind soils varies inbetween the two limits given above and it would be difficult to distinguish the yellow-red from the green-red when the proportions of sand and clay of fractions are inbetween these two extremes. It was, however, noted that the yellow-red type was dis inguishable when the soil was composed of about 60 per cent or more of sand and 8 to 12 per cent of clay. Under lesser proportion of sand fraction yellowing prior to reddening could not be properly distinguished.

YELLOW-RED LEAF IN SIND-AMERICAN COTTONS

It was experimentally proved in the cotton season of 1943-44 that the yellow-red leaf occurred on account of a deficiency of nitrogen in such light sandy lands. A light sandy field where the red

leaf was reported to occur in previous seasons was selected at Denisar Estate, Nabisar Road, Sind. A sowing date-cum-manurial experiment consisting of eight randomized blocks of four main plots each, for four different sowing dates was laid out. Each main plot was split into two sub-plots for control and 33 lb. N per acre treatments. Nitrogen was applied in the form of sulphate of ammonia on the 5th June. The variety was L.S.S., a Punjab-American variety grown on this estate.

Observations on the crop showed that the leaves turned first pale and later red during the fruiting period in the months of August-September in the unmanured plots of the first two sowings while it was green in all the manured plots. The yellow-red leaf generally occurred at a much later date in the 3rd and the 4th sowings of the unmanured plots. Manuring was also found to have a beneficial effect on yields but the increase in yield caused by manuring became less and less as the sowing date advanced (Table II).

TABLE II

Yield in maunds per acre

	Sowing date					
	23/3	6/4	20/4	4/5	Mean	S.E.
Manured	18·1	19·1	17·0	14·5	17·2	$\pm 0{\cdot}50$
Unmanured	11·7	13·5	14·1	13·2	13·1	
Mean ($\pm 0{\cdot}76$)	14·9	16·3	15·6	13·9	15·2	

Another similar experiment to study the effect of the application of sulphate of ammonia on the yellow-red leaf in Sind-American cottons in light sandy land in the middle Sind was laid out in the same season at the Agricultural Research Station, Sakrand. Though the fields select d were light sandy there were saline patches scattered irregularly all over the area. The experiment consisted of three randomized blocks of 12 main plots each in which all combinations of four sowing dates (14th May, 3rd June, 24th June, 17th July) and three nitrogen treatments (control, 40 lb. N per acre in the form of sulphate of ammonia at sowing and 40 lb. N per acre in the form of sulphate of ammonia at flowering) were randomized. Each main plot was split for four varieties (M4, Sind Sudhar, 289F/K25 and 289F/124). Thus it was intended to study the effect of the early and late application of the manure on the development of the red leaf in the case of two Sind-American (M4 and Sind Sudhar) and two Punjab-American varieties (289F/K25 and 289F/124).

The yellowing of the crop was first noticed in the month of September in the first sowing while it did not appear in the fourth sowing in the unmanured plots. The manured plots showed no yellowing except in the case of the first sowing where yellowing developed in October indicating that the dose of nitrogen applied did not prove adequate to prevent yellowing in the early sown crop. It was also noticed that though there was yellowing of the leaves there was very little leaf reddening in this experiment. The crop was however very patchy in most of the plots on account of the presence of alkali or saline patches. In such patches the crop did not show yellowing.

There was a significant increase in the mean yield of all varieties as a result of late application of sulphate of ammonia. The early (at sowing) or the late (at flowering) application of the fertilizer proved equally effective in increasing the yield of two early maturing varieties M4 and 289F/124 while the late application of sulphate of ammonia proved more efficacious than the early application in the case of two late maturing varieties, Sind Sudhar and 289F/K25. Thus application of sulphate of ammonia lessened the yellowing of leaves and increased the yields. It also increased the seed maturity as the boll weight determinations showed (Table III at B). There was significant increase in boll weight (*i.e.*, seed cotton per boll in gm.) in manured plots and late application was found to give the maximum increase in boll weight.

Further experimental evidence to show that a low nitrogen content of the leaves was associated with the yellow-red leaf was obtained in the cotton season of 1944-45. A common experiment on sandy fields at three places, viz., Nabisar Road, Hyderabad and Sakrand was laid out. It consisted of all combinations of two sowing dates, two levels of nitrogen (0, 50 lb N at flowering) and two spacings ($s1 = 2$ ft. and $s2 = 2\frac{1}{2}$ ft. between rows). Each plot was split to accommodate three varieties M4, Sind Sudhar, and L.S.S. In order to correlate the yellow-red leaf with nitrogen content, fortnightly leaf samples from two replications of all the 24 combinations in the experiment at two centres, viz., Nabisar Road and Hyderabad were taken. Four plant sample under wide spacing and eight plant sample under close spacing were taken at random in duplicate. The leaves were analyzed for nitrogen. Regular observations were recorded on the appearance of the red leaf under each treatment at the time of sampling. The results of nitrogen contents of the leaves are given in Table IV.

The study of the results of the nitrogen contents of the leaves in relation to the time of appearance and the spread of the yellow-red leaf at the two centres disclosed in general terms the following relationships between the yellow-red leaf and the nitrogen contents of the leaves under different treatments.

M4 on the whole showed the least yellowing and reddening of the leaves while L.S.S. showed the symptoms at a very early stage and in a very intense form. The crop of M4 remained green even in the unmanured condition up to the end of the fruiting season while L.S.S. showed yellowing and reddening even in the manured plots of the first and in some cases of the second sowing. The concentration of nitrogen in the leaves of M4 remained significantly higher at each stage of growth than the concentration of nitrogen in the leaves of the other two varieties. The leaves of L.S.S showed the least concentration of nitrogen (Table IV). Thus yellow-red leaf appeared to be definitely related to the nitrogen concentration in the leaves.

The manured plots of all the varieties showed much less yellowing and reddening than the corresponding unmanured plots during the fruiting period. These symptoms appeared only in the leaves in some of the manured plots of the first sowings of L. S.S. or Sind Sudhar. The concentration of nitrogen in the leaves of the manured plots was also found to be significantly higher at each stage of growth than the concentration of nitrogen in the leaves of the control plots (Table IV).

The late-sown crop generally showed less yellowing and reddening than the crop sown early. The concentration of nitrogen in the leaves of the late-sown crop was found to be significantly higher at each stage of growth than the concentration of nitrogen in the leaves of early-sown crop.

It was clear that yellowing and reddening of the leaves in American cottons in Sind was associated with a low concentration of nitrogen and was a symptom of nitrogen deficiency. It may be stated here that the selection of plants for analysis of the leaves was at random. The plants were first randomized and then taken for analysis at each date. The term yellowing-reddening used above does not necessarily mean that each and every plant in a plot or all the leaves of a plant had turned yellow-red. Though the general appearance of the crop in a plot indicated yellowing, some leaves of some of the plants may be green or pale green.

The above mentioned conclusions regarding the relation of nitrogen content and the yellow-red leaf were further supported by the yield data obtained in the common experiment (Table V).

M4 gave the highest yield both under manured and unmanured conditions at all the three centres. It had the highest nitrogen content and was found resistant to yellow-red leaf. Manuring gave substantial increases in yields varying from 2·62 to 5·40 maunds per acre. It has already been shown above that manuring had increased the nitrogen content and had at the same time decreased the red leaf.

Explanation of the frequent occurrence of the red leaf trouble in south Sind

The complaints of red leaf were generally received more frequently from southern parts of Sind than from middle Sind. The yellow-red leaf was found to be generally present in many fields in the former tract. How can the greater prevalence of this trouble in the southern parts of Sind be explained if nitrogen deficiency in light sandy soil was the root cause of this trouble as light sandy lands were as widely distributed in middle Sind as in south Sind ? The red leaf trouble was found to be

TABLE III

Effect of the application of sulphate of ammonia on yellow-red leaves

	A Yield in maunds per acre					B Weight of seed cotton per boll in gm.			
	Control	Sulphate of Ammonia before sowing (40 lb. N per acre)	Sulphate of ammonia at flowering (40 lb. N per acre)	Mean (±0·51)		Con-trol	Sulphate of ammo-nia before sowing (40 lb. N per acre)	Sulphate of ammo-nia flower-ing (40 lb. N per acre)	Mean (±0·092)
M4	11·0	13·7	13·5	12·8	M4	2·65	2·93	2·93	2·84
Sind Sudhar	9·8	10·4	13·1	11·1	Sind Sudhar	2·22	2·36	2·49	2·35
289F/K25	9·8	11·7	14·3	11·9	289F/K25	2·54	2·58	3·05	2·72
289F/124	9·7	12·7	13·2	11·9	289F/124	2·71	2·78	2·83	2·77
Mean (±0·85)	10·1	12·2	13·5		Mean (±0·102)	2·53	2·66	2·82	

TABLE IV

Mean percentage nitrogen in leaves on different dates at two centres

Denisar

Date of sampling	M4	Sind Sudhar	L.S.S.	S.E.
	Varieties			
28th July	3·22	2·96	2·83	0·041
13th August	3·08	2·87	2·75	0·047
29th August	2·51	2·30	2·21	0·035
14th September	2·21	1·88	1·74	0·058
	Nitrogen			
	Manured	Control	S.E.	
28th July	3·32	2·68	0·052	
13th August	3·31	2·49	0·055	
29th August	2·66	2·03	0·062	
14th September	2·14	1·75	0·058	
	Sowing date			
	Late sowing	early sowing	S.E.	
28th July	3·11	2·89	0·052	
13th August	3·22	2·58	0·055	
29th August	2·50	2·19	0·062	
14th September	2·12	1·78	0·058	

Hyderabad

Date of sampling	M4	Sind Sudhar	L.S.S.	S.E.
	Varieties			
23rd July	3·47	3·19	2·96	0·028
7th August	3·14	2·91	2·70	0·020
23rd August	2·66	2·46	2·50	0·022
7th September	2·31	2·07	1·87	0·022
23rd September	1·79	1·64	1·47	0·031
	Nitrogen			
	Manured	Control	S.E.	
23rd July	3·39	3·02	0·035	
7th August	3·03	2·80	0·034	
23rd August	2·78	2·29	0·043	
7th September	2·28	1·88	0·029	
23rd September	1·70	1·56	0·034	
	Sowing date			
	Late sowing	Early sowing	S.E.	
23rd July	3·49	2·92	0·035	
7th August	3·18	2·65	0·034	
23rd August	2·85	2·22	0·043	
7th September	2·38	1·78	0·029	
23rd September	1·79	1·47	0·034	

even of less frequent occurrence in the Punjab than in middle Sind even though there are vast areas in the Punjab which are light sandy.

TABLE V

Yield in maunds per acre

—	Denisar		Hyderabad		Sakrand		Mean		Increase due to manuring
	Control	Manured	Control	Manured	Control	Manured	Control	Manured	
M4	10·36	14·17	14·67	18·84	11·55	15·66	12·19	16·23	+4·04
Sind Sudhar	7·56	8·94	11·06	14·61	9·89	15·20	9·50	12·92	+3·42
L.S.S.	8·86	11·50	12·38	17·91	7·98	14·75	9·74	14·72	+4·98
Mean	8·92	11·54	12·70	17·12	9·80	15·20	10·48	14·62	+4·14
Increase due to manuring	+2·62		+4·42		+5·40		+4·14		
S.E. (Varieties)	±0·251=2·45 per cent		±0·326=2·19 per cent		±0·695=5·58 per cent				
S.E. (Nitrogen)	±0·502=4·91 per cent		±0·549=3·68 per cent		±0·587=4·71 per cent				

Further investigations conducted on this problem have revealed that the widespread occurrence of yellow-red leaf in southern parts of Sind was a result of the interaction of soil factor with the climatic factors prevailing in that tract.

Two Sind-American varieties, M4 and Sind Sudhar, and one Punjab-American variety, L.S.S., were grown at three centres in south Sind (Denisar Estate, Nabisar Road), in middle Sind (Sakrand) and in the Punjab (Iqbal Nagar). A common sowing date-cum-varietal experiment was laid out at the three centres. Though the object of the experiment was to study the growth of these three varieties under different sowing dates and under the climatic conditions prevailing in the three tracts, the observations made on the onset and the completion of the reproductive phase provided evidence for the cause of such frequent and widespread occurrence of the yellow-red leaf disease in south Sind. During the above mentioned study regular observations on the initiation and the completion of the reproductive phase of each of the three varieties at the three centres were recroded with a view to determine the main flowering period and the harvesting period. It was expected to provide information regarding the relation of climatic factors with the initiation and the completion of the reproductive phase of a variety. The main flowering and harvesting periods at the three centres for each variety are given in Table VI.

TABLE VI

Main flowering and harvesting periods of the three varieties at the three centres

	South Sind (Denisar Estate)	Middle Sind (Sakrand)	Punjab (Iqbal Nagar)
	(a) Flowering periods		
M4	17th July to 17th August	10th August to 10th September	16th August to 13th September
Sind Sudhar	5th August to 15th September	20th August to 20th September	23rd September to 19th October
L.S.S.	30th July to 30th August	25th August to 20th September	15th September to 15th October
	(b) Harvesting periods		
M4	September to October	October to December	October to December
Sind Sudhar	Mid-September to early November	November to January	November to January
L.S.S.	do.	do.	do.

In south Sind there was an early initiation of flowering and setting and early completion of the fruiting phase and consequently early finishing of the crop. The general pickings in this tract started by the first or the second week of September and were almost completed by the end of October or beginning of November at the latest while in middle Sind and the Punjab the pickings began by the second or the third week of October and were almost complete by the end of December. The crop finished off more quickly, *i.e.*, in less than two months, in south Sind than in middle Sind and in the Punjab. This difference in the setting and maturation of the crop could be explained by the differences in the climatic conditions prevailing in these tracts and these will be pointed out below.

Earliness or lateness of a variety is its inherent character but it can be modified by the climatic factors, as has been clearly brought out by this investigation. An early maturing variety may become late in a different environment and vice versa. L.S.S. which is a late maturing variety in its natural environment in the Punjab became early when grown in south Sind. It flowered, fruited and finished off earlier in the latter tract than in the former tract and in middle Sind (Table VI). Similarly M4 which is an early Sind variety became comparatively late under the Punjab and middle Sind conditions. Thus the inherent character of earliness or lateness could be shifted forward or backward by climatic conditions even though the relative differences between an early and a late variety would still persist in a given environment (Table VI). M4 always matured earlier than L.S.S. in south Sind or in the Punjab while L.S.S. always matured later than M4 in the same two tracts (Table VI).

The differences between the flowering and the harvesting periods in south Sind on one hand and the middle Sind and the Punjab on the other hand could be explained on the basis of the differences in the maximum and minimum temperatures and humidity prevailing in these tracts (Table VII).

TABLE VII

Monthly means of maximum and minimum temperatures and humidity

—	April	May	June	July	August	September	October	November	December	January
			South Sind (Hyderabad)							
Maximum . . .	102·0	107·2	104·2	99·2	95·9	97·4	97·9	89·1	79·0	76·2
Minimum . . .	72·1	78·2	81·7	80·9	79·0	76·2	70·1	58·9	52·3	50·6
Humidity at 8 A.M. .	47	54	62	68	70	68	56	52	55	57
			Middle Sind (Sakrand)							
Maximum . . .	102·0	111·0	110·0	104·0	102·0	102·0	101·0	89·0	78·0	74·0
Minimum . . .	67·0	77·0	83·0	83·0	80·0	75·0	65·0	54·0	46·0	43·0
Humidity at 8 A.M. .	53	53	63	71	73	74	68	69	76	73
			Punjab (Multan)							
Maximum . . .	97·9	106·9	108·3	104·3	101·2	100·5	95·9	84·8	73·5	69·7
Minimum . . .	68·4	78·1	84·2	84·3	82·6	77·5	65·1	53·5	45·0	43·3
Humidity at 8 A.M. .	47	42	50	63	68	65	56	60	69	71

There was an early fall in the maximum temperature from the month of July in south Sind and it remained lower throughout the remaining part of the season. The minimum temperatures were throughout higher during the fruiting and maturation period (August — October) in south Sind while in middle Sind and the Punjab the later part (October — December) of the fruiting and maturation period was characterized by a rapid fall in the night temperatures. The differences between maximum and minimum temperatures are also of a lower magnitude in south Sind. These differences in temperature between south Sind and middle Sind and the Punjab may be responsible for the early initiation, setting and maturation of the crop in the first tract, as explained below.

The fall in the maximum temperatures in July in south Sind gave rise to an early initiation of fruiting branches. High temperatures as shown by Balls [1919] retard the stem growth as well as the formation of flowering branches. The fruiting branches are not formed as soon as the temperatures

drop but its effect becomes visible after a lapse of certain period from the day the temperature begins to fall. The lower temperatures in August in south Sind also helped in the setting of bolls. As there was no great fall in the night temperature which remained well above 70°F. during the bolling and maturation period, the bolls matured very rapdily. As a result of numerous determinations it was found that the maturation period of bolls for all the three varieties generally varied from 33 to 39 days. The crop therefore became early and finished off early, before the night temperatures fell below 70°F.

In middle Sind and the Punjab the temperatures began to fall in August and the initiation and the setting of the crop began to occur from the middle of August or the beginning of September according to early or late habit of a variety. The maturation period of bolls coincided with falling night temperatures. The night temperatures in October fell below 70°F. and they were still lower in the months of November and December (Table VII). Consequently maturation occurred at a slower rate so much so that the maturation period of bolls increased from 45 days to 70 days. The maturation period of bolls of all varieties was found to increase from 40 days in the bolls set in August to 70 days for bolls set in October. The late set bolls continued to open up till the end of December or beginning of January in the late maturing varieties.

The entire flowering period in south Sind was also found to be comparatively shorter than in the Punjab and consequently the boll formation also ceased earlier. This may be an additional factor that contributed to an early finishing of the crop in south Sind.

Though no differences in humidity recorded at 8 A.M. were found to exist in the three tracts during the reproductive phase, the humidity during the day was known to be higher in south Sind than either in middle Sind or the Punjab. It is also likely that higher humidity during the day may minimise abscission and may thus cause an early setting of bolls. Thus higher humidity may also contribute to an early setting and thus indirectly to an early maturation of the crop.

It has already been shown by the senior author [Dastur and Ahad, 1941 and Dastur, 1941] that the nitrogen content of the leaves began to decline when the reproductive phase set in and the leaves began to turn pale and yellow when their nitrogen content fell to 1·5 per cent of the dry matter of the leaves. The rapid maturation of the crop in south Sind brought about a quick depletion of nitrogen in the leaves and the nitrogen content of the leaves, therefore, fell much below that level when yellowing started. The nitrogen contents of Sind Sudhar and L.S.S. under unmanured condition had fallen to 1·5 per cent as early as the first week of September (Table VIII) in the April-sown crop. The drain of nitrogen in the leaves was so great that young and mature leaves along with old leaves were found to turn pale and yellow. The nitrogen content of the leaves on manured land remained much above 1·5 per cent during the maturation period and consequently yellowing did not occur even though the crop matured equally rapidly.

The cotton crop under middle Sind and the Punjab conditions matured slowly on account of a fall in temperature in October and there was, therefore, no such rapid depletion of nitrogen from the leaves. The nitrogen content of the leaves of 4F remained above 1·5 per cent up to the end of November. It was higher even in the month of November in the Punjab than in the month of September in south Sind in the May-sown crop (Table VIII).

The yellowing, therefore, occurred in the Punjab towards the end of the maturation period except on light sandy lands. On the latter type of land yellowing occurred towards the end of September and it was found to be accompanied with a low nitrogen content in the leaves.

Conclusions

The yellowing and the subsequent reddening in *hirsutum* cottons in Sind, therefore, occurred on account of the operation of two factors : (1) light sandy lands deficient in nitrogen and (2) higher night temperatures during the fruiting period causing a rapid maturation of the crop. In the Punjab and middle Sind yellowing occurred on account of the operation of the soil factor alone. Light sandy soils are widely distributed in all the three tracts but quick maturation of the crop in south Sind on

TABLE VIII

Percentage of nitrogen in leaves in south Sind and the Punjab

Date	Hyderabad (south Sind)						Date	Lyallpur (Punjab)	
	Sown on 15th April			Sown on 22nd May				Sown on 14th May 4F	Sown on 21st June 4F
	M4	S.S.	L.S.S.	M4	S.S.	L.S.S.			
23rd July	2·65	2·32	2·29	3·76	3·29	3·07	24th July	3·78	4·42
7th August	2·56	2·07	2·00	3·33	3·22	2·89	8th August	3·16	3·40
23rd August	2·32	1·83	1·89	2·14	2·08	2·09	22nd August	2·78	3·37
7th September	1·95	1·55	1·49	2·14	1·87	1·77	5th September	2·39	3·25
23rd September	1·65	1·30	1·15	1·88	1·46	1·46	19th September	2·33	2·69
							3rd October	2·46	2·72
							18th October	2·24	2·37
							1st November	1·73	2·35
							15th November	1·88	2·13

account of the prevailing higher night temperatures at that time caused the trouble to spread on lands which were not very deficient in nitrogen, i.e., it spread to lands where normally the premature yellowing did not occur under Punjab conditions. The red leaf trouble was, therefore, more widespread in south Sind than in the other two tracts. The variations in the nitrogen status of the soil from field to field caused variations in the intensity and the time of its appearance. The intensity and the spread of the red leaf trouble can also increase in south Sind if the month of September was characterized by spells of higher temperatures than normal as they would further hasten the maturation process and quicken the depletion of nitrogen from the leaves. Wherever there was quick depletion of nitrogen, the entire plant turned yellow-red while wherever the depletion was not so quick, some leaves turned yellow and some remained normal. The time of appearance and the intensity of the yellow-red leaf trouble would also be influenced by the previous crop, by manuring and by fallowing.

The remedial measure for minimising the yellow-red leaf in Sind American cottons in south Sind along with the method to be adopted for giving practical effect on *zamindars*' lands will be described in the next contribution.

SUMMARY

As the red leaf in American upland cottons (*G. hirsutum*) has been reported to occur from different parts of India where the soil and climatic conditions are known to vary greatly, it appeared that the causes that give rise to this symptom of reddening may also be different. It was, therefore, undertaken to investigate the problem in the irrigated tract of Sind and the rain-fed tract of the central India. The present paper deals with the investigations conducted in Sind.

Two types of reddening depending on the physical properties of the soil have been discovered; one type in which the change in colour occurs from green to yellow and then to red and the second type where the change is direct from green to red. These are two extremes between which intermediate stages in the two types of reddening may be found.

Complete experimental evidence has been produced to show that the yellow-red leaf was caused by a deficiency of nitrogen in the leaves of plants growing on light sandy lands. The leaves of plants which showed this type of reddening during the fruiting phase contained significantly less nitrogen than the leaves of plants which were green in colour.

M4 which showed these symptoms in the least degree was found to contain higher concentration of nitrogen in the leaves at each stage of growth than the leaves of L.S.S. and Sind Sudhar which suffered most from this 'disease'.

The plants manured with sulphate of ammonia did not show the yellow-red leaf while the symptom was found to be present in the unmanured plants in the same field.

Late sown crop showed less yellow-red leaf than the early sown plants and the nitrogen concentration was higher in the former than in the latter.

In addition to the amelioration of yellow-red leaf, manuring significantly increased the yields of seed cotton per acre.

The more frequent and widespread occurrence of the yellow-red leaf in south Sind than in middle Sind and in the Punjab even though sandy lands are common in all the three tracts, has now been explained. The addition to the soil factor, viz., sandy nature of the soil, the climatic conditions in south Sind operated in the widespread occurrence of the yellow-red leaf in that region. On account of an early drop in the temperature in July there was an early initiation of flowering. Higher day humidity in this tract reduced abscission and favoured setting of bolls. The maturation period in August, September and October coincided with high night temperatures which hastened the boll development. A large number of determinations revealed that the maturation period of bolls varied from 33 to 39 days. The crop finished off in two months, i.e., in September—October. In the Punjab there was late initiation of flowering in September on account of very high temperatures in July and August and the fruiting period therefore coincided with falling night temperatures in October, November and December. The maturation period of bolls was found to vary from 45 days to 70 days. The crop finished off at the end of December or the beginning of January.

The rapid maturation of the crop in south Sind caused heavy depletion of nitrogen from the leaves which consequently became senescent, turned yellow and red. Thus the red leaf trouble was accentuated and it spread to lands where normally this 'disease' did not appear under middle Sind and the Punjab conditions.

A practical method of locating such fields where this trouble is likely to occur is being worked out and will be reported in the next contribution.

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MANURIAL REQUIREMENTS OF RICE IN THE CENTRAL PROVINCES

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(With Plates XVI and XVII)

In the report on the work of the Imperial Council of Agricultural Research in applying science to crop production in India, Sir John Russell recommended that more systematic schemes of manurial trials were necessary in order to test the relative values of nitrogen in artificial fertilizers, farmyard manure and composts, and the values of phosphate and potash. Acting on these recommendations, the sub-committee on field and manurial experiments, at its meeting held in November 1938, recommended standard designs for manurial experiments on rice to be carried out at different centres. Experiments on the effect of nitrogenous and phosphatic fertilizers alone and in combination, and on organic and inorganic manures and their mixtures were started at the Rice Research Station, Raipur, in 1939 and were continued for five years. Investigations on the effect of oil-cakes and compost were begun in 1942 and have been continued for three years. The results of these experiments are summarized in this paper.

Previous work

The results of manurial experiments on rice carried out at Government farms, Raipur, Waraseoni and Jubbulpore, prior to 1930, have been reviewed by Allan [1932]. These trials have shown that both cattle-dung (6,000 lb. per acre) and green manure Sunn hempor *Crotalaria juncea*, (8,000 lb. per acre) are very effective in bringing about significant increases in yield over no manure and the addition of phosphates (2 cwt. bone-meal per acre) considerably increases the efficiency of bulky organic manures. Green-manuring, however, is restricted to areas where irrigation before the monsoon is an economic possibility and this renders the practice unlikely to have any widespread application.

On the lighter soils the application of soluble phosphoric acid (1 cwt. superphosphate per acre) is profitable and distinctly more effective than bonemeal. In absence of phosphoric acid, the effect of nitrogenous fertilizer (ammonium sulphate) is barely significant.

The application of Nicifos II at 180 lb. per acre is profitable.

The results of manurial experiments on rice conducted in the Provinces and States of India during 1932-38 have been analyzed in the publications of the Imperial Council of Agricultural Research [Vaidyanathan, 1938] and have been brought together in the form of a bulletin by Sethi [1940]. Sukhatme [1941] has presented a test of significance for profit which has been adopted in this paper.

Experimental results

Experiment 1 (a)—Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of paddy. Soil—Heavy, Dorsa (clay loam)

Design. The experiment was a $3 \times 3 \times 3$ factorial design with four replications, each replicate having 27 treatment combinations. Three sub-blocks of nine plots each were used in each replication, confounding 2 degrees of freedom with block differences.

Treatments (rates of application). The factors employed were—

Nitrogen at three levels -0, 10 and 20 lb. per acre, in the form of ammonium sulphate (20 per cent N.).

Phosphoric acid at three levels -0, 10 and 20 lb. per acre, in the form of double superphosphate (40 per cent P_2O_5).

Varieties—three, R6 Budhiabako (late), R10 Chhatri (fine, scented, medium ripening) and R2 Nungi (early).

The experimental field was located in block V of Labhandi farm, Raipur.

The soil was of a heavy type -*Dorsa* (clay loam)—containing nearly 48 per cent clay, 5 per cent fine silt and 8 per cent silt (Appendix A).

The ultimate size of the plot was 1/40th acre ($17\frac{1}{3}$ ft. × $61\frac{1}{4}$ ft.) with $2\frac{1}{3}$ ft. as non-experimental margin.

Agricultural. The method of cultivation was *biasi.** No basal manuring was given and the fertilizers were applied two weeks after *biasi.* The crop was irrigated and the rotation every year was rice after rice.

TABLE I

Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of paddy

Combined results of five years, 1939 to 1943

Soil.—Dorsa (*clay loam*)

Treatments	Average yield five years in lb.	Increase over no manure in lb.	Percentage of increase over no manure	At pre-war prices—August 1939: Value of extra yield	Cost of ferti-lizers	Profit or loss	At rates prevailing in December 1943: Value of extra yield	Cost of ferti-lizers	Profit
				R6 Budhiabako (late)					
Per acre	Per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
0 lb. N + 0 lb. P_2O_5	988	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	1,197	209	21	4 3	1 15	2 4	13 15	4 6	9 9
0 lb. N + 20 lb. P_2O_5	1,233	245	25	4 14	3 15	0 15	16 5	8 12	7 [illegible]
10 lb. N + 0 lb. P_2O_5	1,372	384	39	7 11	2 15	4 12	25 10	6 2	19 8
10 lb. N + 10 lb. P_2O_5	1,592	604	61	12 1	4 14	7 3	40 4	10 8	29 12
10 lb. N + 20 lb. P_2O_5	1,659	671	68	13 7	6 13	6 10	44 12	14 14	29 14
20 lb. N + 0 lb. P_2O_5	1,501	513	52	10 4	5 13	4 7	34 3	12 4	21 15
20 lb. N + 10 lb. P_2O_5	1,676	688	70	13 12	7 12	6 0	45 14	16 10	29 4
20 lb. N + 20 lb. P_2O_5	2,122	1,134	115	22 11	9 12	12 15	75 10	21 0	54 10
					Cr. diff. Rs. 3-3-9			Cr. diff. Rs. 10-13-0	
				R10 Chhatri (fine, scented, medium ripening)					
0 lb. N + 0 lb. P_2O_5	902	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	982	80	9	1 12	1 15	—0 3	5 11	4 6	1 5
0 lb. N + 20 lb. P_2O_5	1,105	205	23	4 9	3 15	0 10	14 10	8 12	5 14
10 lb. N + 0 lb. P_2O_5	1,124	222	25	4 15	2 15	2 0	15 14	6 2	9 12
10 lb. N + 10 lb. P_2O_5	1,290	388	43	8 10	4 14	3 12	27 11	10 8	17 3
10 lb. N + 20 lb. P_2O_5	1,222	320	36	7 2	6 13	[illegible]	[illegible]	14 14	8 0
20 lb. N + 0 lb. P_2O_5	1,279	377	42	8 6	5 13	[illegible] 9	26 15	12 4	14 11
20 lb. N + 10 lb. P_2O_5	1,445	543	60	12 1	7 12	4 5	38 13	16 10	22 3
20 lb. N + 20 lb. P_2O_5	1,639	737	82	16 6	9 12	6 10	52 10	21 0	31 10
					Cr. diff. Rs. 3-9-9			Cr. diff. Rs. 11-9-3	
				[illegible]					
0 lb. N + 0 lb. P_2O_5	745	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	897	152	20	2 11	1 15	0 12	10 2	4 6	5 12
0 lb. N + 20 lb. P_1O_5	989	244	33	4 6	3 15	0 7	16 4	8 12	7 8
10 lb. N + 0 lb. P_2O_5	947	202	27	3 10	2 15	0 11	13 7	6 2	7 5
10 lb. N + 10 lb. P_2O_5	999	254	34	4 9	4 14	—0 5	16 15	10 8	6 7
10 lb. N + 20 lb. P_2O_5	1,119	374	50	6 11	6 13	—0 2	24 15	14 14	10 1
20 lb. N + 0 lb. P_2O_5	1,165	420	56	7 8	5 13	1 11	28 0	12 4	15 12
20 lb. N + 10 lb. P_2O_5	1,171	426	57	7 10	7 12	0 2	28 6	16 10	11 12
20 lb. N + 20 lb. P_2O_5	1,441	696	93	12 7	9 12	2 11	46 6	21 0	25 6
					Cr. diff. Rs. 2-11-3			Cr. diff. Rs. 10-13-0	

* *Biasi.*—A method of rice cultivation in which seed is sown broad-cast, followed by ploughing to thin out the seedlings when they are a foot high.

The treatments were—

Nitrogen at two levels 0 and 10 lb. per acre, in the form of ammonium sulphate.

Phosphoric acid at two levels 0 and 10 lb. per acre, in the form of double superphosphate.

Methods of cultivation—Two, transplantation and *biasi*.

Varieties—Two, R6 Budhiabako (late) and R2 Nungi (early).

The experimental field was located in block VI of Labhandi farm.

The soil was *Matasi* (sandy loam), of average fertility, containing nearly 25 per cent clay, 4 per cent fine silt and 9 per cent silt. (Appendix A).

The ultimate size of the plot was 1/40th acre ($17\frac{1}{3}$ ft. × $61\frac{1}{3}$ ft.) with $2\frac{1}{3}$ ft. as non-experimental margin.

No basal manuring was given and fertilizers were applied at the time of transplantation and two weeks after *biasi*. The crop was irrigated and the rotation was rice after rice.

TABLE II.

Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of transplanted and 'biasi' rice

Combined results of five years, 1939 to 1943

Soil—Matasi (*sandy loam*)

Treatments	Average yield (five years) in lb.	Increase over no manure, in lb.	At pre-war prices—August 1939				At rates prevailing in December 1943		
			Percentage of increase over no manure	Value of extra yield	Cost of fertilizers	Profit or loss	Value of extra yield	Cost of fertilizers	Profit
			Transplanted						
			R6 Budhiabako (late)						
(Per acre)	Per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
0 lb. N + 0 lb. P_2O_5	1,158		..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	1,355	197	17	3 15	1 15	2 0	13 2	4 6	8 12
10 lb. N + 0 lb. P_2O_5	1,519	361	31	7 4	2 15	4 5	24 1	6 2	17 15
10 lb. N + 10 lb. P_2O_5	1,851	693	60	13 14	4 14	9 0	46 3	10 8	35 11
				Cr. Diff. Rs. 2-6-6			Cr. Diff. Rs. 8-0-9		
			R2 Nungi (early)						
0 lb. N + 0 lb. P_2O_5	914	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	1,095	181	20	3 4	1 15	1 5	12 1	4 6	7 11
10 lb. N + 0 lb. P_2O_5	1,279	365	40	6 8	2 15	3 9	24 5	6 2	18 3
10 lb. N + 10 lb. P_2O_5	1,487	573	63	10 4	4 14	5 6	38 3	10 8	27 11
				Cr. Diff. Rs. 2-2-6			Cr. Diff. Rs. 8-0-9		
			Biasi						
			R6 Budhiabako (late)						
0 lb. N + 0 lb. P_2O_5	1,115		..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	1,252	137	12	2 12	1 15	0 13	9 2	4 6	4 12
10 lb. N + 0 lb. P_2O_5	1,309	194	17	3 14	2 15	0 15	12 15	6 2	6 13
10 lb. N + 10 lb. P_2O_5	1,491	376	34	7 8	4 14	2 10	25 1	10 8	14 9
				Cr. Diff. Rs. 2-6-6			Cr. Diff. Rs. 8-0-9		

TABLE II—*contd.*

Effect of nitrogenous and phosphatic fertilzers applied alone and in combination on the yield of transplanted and 'biasi' rice—contd.

Combined results of five years, 1932 to 1943—contd.

Treatment	Average yeild (five years) in lb.	Increase over no manure in lb.	Percentage of increase over no manure	At pre-war prices—August 1939. value of extra yeild	Cost of fertilizers	Profit or loss	At rates prevailing in December 1943 value of extra yeild	Cost of fertilisers	Profit
			R2 Nungi (early)						
0 lb. N + 0 lb. P_2O_5	738	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	842	104	14	1 14	1 15	—0 1	6 15	4 6	2 9
10 lb. N + 0 lb. P_2O_5	958	220	30	3 15	2 15	1 0	14 11	6 2	8 9
10 lb. N + 10 lb. P_2O_5	1,113	375	51	6 11	4 14	1 13	25 0	10 8	14 8
						Cr. Diff. Rs. 2-2-6		Cr. Diff. Rs. 0-8-9	

S. E. of Tr. mean 43·58 — 'Z' test — Cr. Diff. P = 0·05 120·8

Nitrogen.—Significant at 1 per cent.

Phosphoric acid.—Significant at 1 per cent.

Cultivation methods.—Significant at 1 per cent.

Varieties.—Significant at 1 per cent.

N × C.—Significant at 1 per cent.

V × C.—Significant at 5 per cent.

Remaining interactions.—Insignificant

Conclusions —

Transplanted.

R6 Budhiabako

10 lb. N, 10 lb. P ⊳ 10 lb. N ⊳ 10 lb. P ⊳ No manuure

R2 Nungi

10 lb. N, 10 lb. P ⊳ 10 lb. N ⊳ 10 lb. P ⊳ No manure

Biasi

R6 Budhiabako

10 lb. N, 10 lb. P ⊳ 10 lb. N 10 lb. P ⊳ No manure

R2 Nungi

10 lb. N, 10 lb. P ⊳ 10 lb. N 10 lb. P No manure

The results show that on light soils (*Matasi*, sandy loam) the combination of nitrogenous and phosphatic fertilizers has given the highest yield and the largest net profit. The application of 10 lb. nitrogen in the form of ammonium sulphate with 10 lb. phosphoric acid in the form of double superphosphate per acre has given significantly higher yield than either 10 lb. nitrogen or 10 lb. phosphoric acid applied alone. With transplanted rice, 10 lb. nitrogen per acre is significantly better than 10 lb. phosphoric acid, and 10 lb. phosphoric acid significantly better than no manure.

The application of 10 lb nitrogen with 10 lb. phosphoric acid (50 lb. ammonium sulphate with 25 lb. double superphosphate) per acre increased the yield of late paddy R6 Budhiabako from 1,158 lb. to 1,851 lb., an increase of 60 per cent and of early paddy R2 Nungi from 914 lb. to

1,487 lb., an increase of 63 per cent, when both were transplanted. The net profits per acre (compared with the application of ammonium sulphate alone) were as follows :

Treatments	Increase over no manure lb.	Percentage of increase over no manure	Profit: At pre-war rates—August 1939	Profit: At rates prevailing in December 1943
(Per acre)			Rs. a.	Rs. a.
	R6 Budhiabako (late)			
50 lb. Ammonium sulphate + 25 lb. double superphosphate	693	60	9 0	35 11
50 lb. Ammonium sulphate	361	31	4 5	17 15
	R2 Nungi (early)			
50 lb. ammonium sulphate + 25 lb. double superphosphate .	573	63	5 6	27 11
50 lb. Ammonium sulphate	365	40	3 9	18 3

Table III.

Effect of nitrogenous and phosphatic fertilizers applied alone and in different combinations
Combined results of three years, 1935 to 1937

Soil.—Very light, shallow Matasi *(sandy loam) 9 inches deep*

Treatments	Average yield (five years) lb.	Increase over no manure lb.	Percentage of increase over no manure	At pre-war prices—August 1939: Value of extra yield	Cost of fertilizers	Profit or loss	At rates prevailing in December 1943: Value of extra yield	Cost of fertilizers	Profit or loss
(Per acre)	Per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
0 lb. N + 0 lb. P_2O_5 . . .	879	..	..	..	..	..	..	..	..
0 lb. N + 20 lb. P_2O_5 . . .	1,326	447	51	8 0	3 14	4 2	29 13	8 12	21 1
0 lb. N + 30 lb. P_2O_5 . . .	1,333	454	52	8 2	5 13	2 5	30 4	13 2	17 2
0 lb. N + 40 lb. P_2O_5 . . .	1,388	509	58	9 1	7 12	1 5	33 15	17 8	16 7
20 lb. N + 0 lb. P_2O_5 . . .	903	24	3	0 7	5 14	—5 7	1 10	12 4	—10 10
20 lb. N + 20 lb. P_2O_5 . . .	1,582	703	80	12 9	9 12	2 13	46 14	21 0	25 14
20 lb. N + 30 lb. P_2O_5 . . .	1,637	758	86	13 9	11 11	1 14	50 9	25 6	25 3
20 lb. N + 40 lb. P_2O_5 . . .	1,661	782	89	13 15	13 10	0 5	52 2	29 12	22 6
30 lb. N + 0 lb. P_2O_5 . . .	920	41	5	0 12	8 13	8 1	2 12	18 6	—15 10
30 lb. N + 20 lb. P_2O_5 . . .	1,617	738	84	13 3	12 11	0 8	49 3	27 2	22 1
30 lb. N + 30 lb. P_2O_5 . . .	1,799	920	105	16 7	14 10	1 13	61 5	31 8	29 13
30 lb. N + 40 lb. P_2O_5 . . .	1,761	882	100	15 12	16 9	—0 13	58 13	35 14	22 15
40 lb. N + 0 lb. P_2O_5 . . .	934	55	6	1 0	11 12	—10 12	3 11	24 8	—20 13
40 lb. N + 20 lb. P_2O_5 . . .	1,778	899	102	16 1	15 10	0 7	59 15	33 4	26 11
40 lb. N + 30 lb. P_2O_5 . .	1,818	939	107	16 12	17 9	—0 13	62 10	37 10	250
40 lb. N + 40 lb. P_2O_5 . .	2,011	1,132	129	20 3	19 8	0 11	75 7	42 0	337
					Cr. Diff.	Rs. 4-7-6		Cr. Diff.	Rs. 16-11-6

S. E. of Tr. mean = 90·5. 'Z' test (P = 0·01)—Significant. Cr. Diff. (P = 0·05) = 250·8

Conclusions—

40 N 40 N 30 N 40 N 30 N 20 N 20 N 30 N 20 N 40 N 30 N 20 N No manure.
40 P 30 P 30 P 20 P 40 P 40 P 30 P 20 P 20 P 40 P 30 P 20 P

In *biasi* rice the application of 50 lb. ammonium sulphate, with 25 lb. double superphosphate per acre increased the yield of R6 Budhiabako from 1,115 lb. to 1,491 lb., an increase of 34 per cent. and of R2 Nungi from 738 lb. to 1,113 lb., an increase of 51 per cent. On light soils, with *biasi* system of cultivation, the effect of fertilizers was not so pronounced as under transplantation, indicating that the time of application of fertilizers may be an important factor which needs investigation. Transplanted rice gave significantly higher yield than *biasi* rice.

Experiment 1 (c).—Effect of nitrogenous and phosphatic fertilizers applied alone and in different combinations on the yield of paddy. Soil—Very light and shallow Matasi (sandy loam), 9 inches deep.

The experiment was laid out in randomized blocks with six replications, each replicate having 16 treatment combinations. The treatments were—

Nitrogen at four levels—0, 20, 30 and 40 lb. per acre in the form of ammonium sulphate (20 per cent N).

Phosphoric acid at four levels—0, 20, 30 and 40 lb. per acre in the form of double superphosphate (40 per cent P_2O_5).

The experimental field was located at Chandkhuri farm, Raipur, and the soil was very light, shallow *Matasi* (sandy loam), 9 inches deep. The ultimate size of the plot was 1/50th acre ($13\frac{3}{4}$ ft. $\times$ $63\frac{1}{4}$ ft.) with $1\frac{1}{3}$ ft. as non-experimental margin. The variety was R4 Surmatia (medium in ripening) and the method of cultivation was *biasi*. No basal manuring was given and the fertilizers were applied at the time of *biasi*. The crop was irrigated and rotation was rice after rice.

The results show that on very light, shallow, laterite soils phosphoric acid is the limiting factor. The application of 20 lb. P_2O_5 (50 lb. double superphosphate) per acre increased the yield of paddy from 879 lb. to 1,326 lb., an increase of 51 per cent, and gave the largest net profit, at pre-war rates. Differences in yields due to the application of 20, 30 or 40 lb. phosphoric acid per acre were, however, not significant.

Very light and shallow laterite soils do not respond to the application of nitrogen even to the extent of 40 lb. per acre. The application of nitrogenous fertilizers alone is, therefore, accompanied with loss.

A combination of nitrogenous and phosphatic fertilizers is very effective in bringing about significant increase in yield over phosphates applied alone or over no manure. The most effective nitrogen and phosphate ratio is 1 : 1. The application of 20 lb. nitrogen with 20 lb. phosphoric acid (100 lb. ammonium sulphate with 50 lb. double superphosphate) per acre increased the yield of paddy from 879 lb. to 1,582 lb., an increase of 80 per cent; 30 lb. N+30 lb. P_2O_5 increased the yield from 879 lb. to 1,799 lb., an increase of 105 per cent, and 40 lb. N+40 lb. P_2O_5 increased the yield from 879 lb. to 2,011 lb., an increase of 129 per cent.

Simplified experiments to test the results obtained at the Rice Research Station were laid out, in randomized blocks with five replications, on the cultivators' holdings in 23 important *tahsils* of the rice growing tracts. The results of some of these are summarized below.

The results confirm that highest yield and largest net profit are obtained only when nitrogenous and phosphatic fertilizers are given in combination. The application of 100 lb. ammonium sulphate with either 50 lb. or 25 lb. double superphosphate per acre is profitable and increases the yield, on an average, by 100 and 70 per cent, respectively. If the cultivators are not able to use this quantity of fertilizers (costing Rs. 9-12-0 and Rs. 7-12-0, respectively, at pre-war prices), a dressing of at least 50 lb. ammonium sulphate with 25 lb. double superphosphate per acre (costing Rs. 4-14-0) is recommended. This application of fertilizers will increase the yield, on an average, by 50 per cent and will be definitely profitable.

Experiment 2.—Effect of organic and inorganic manures and their mixtures on the yield of paddy.

The experiment was laid out in randomized blocks with five replications. The treatments were—

(1) No manure.

(2) Inorganic nitrogen, 10 lb. per acre (Ammonium sulphate 50 lb.).

(3) Inorganic nitrogen, 20 lb. per acre (Ammonium sulphate 100 lb.).

(4) Organic nitrogen, 10 lb. per acre (Farmyard manure. Nitrogen in air dry sample 0 8 per cent.)

TABLE IV.

Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of paddy

Treatments	Piprod village, Raipur *tahsil* Soil.—*Matasi* (sandy loam) Average, 1940 and 1941				Kosmandi village, Balodabazar Soil.—*Matasi* 1941				Karhidih village, Mahasamund Soil.—*Matasi* 1941			
	Mean yield per acre	Increase over no manure	Per cent increase over no manure	Profit or loss*	Mean yield per acre	Increase over no manure	Percent increase over no manure	Profit or loss*	Mean yield per acre	Increase over no manure	Per cent increase over no manure	Profit or loss*
	Variety.—R6 Budhiabako (late)											
(Per acre)	Lb.	Lb.		Rs. a.	Lb.	Lb.		Rs. a.	Lb.	Lb.		Rs. a.
0 lb. N + 0 lb. P_2O_5	588	..	..	..	568	..	..	..	1,324	..	..	..
0 lb. N + 10 lb. P_2O_5	800	212	36	2 5	760	192	34	1 14	1,380	56	4	—0 13
10 lb. N + 0 lb. P_2O_5	680	92	16	—1 1	552	—16	—3	—3 3	1,716	392	30	4 15
10 lb. N + 10 lb. P_2O_5	920	332	56	1 13	912	344	61	2 1	1,732	408	31	8 6
20 lb. N + 0 lb. P_2O_5	628	40	7	—5 0	592	24	4	—5 5	1,822	498	38	4 2
20 lb. N + 10 lb. P_2O_5	1,020	432	73	0 14	1,064	496	87	2 3	1,922	598	45	4 3
20 lb. N + 20 lb. P_2O_5	1,552	964	164	9 9	1,312	744	131	5 3	2,000	676	51	3 12
	S. E. of Tr. mean	'Z' test P=0·01	Cr. diff. P=0·05		S. E. of Tr. mean	'Z' test P=0·05	Cr. diff. P=0·05		S. E. of Tr. mean	'Z' test P=0·01	Cr. diff. P=0·05	
	109·6	Significant	320·0		65·8	Significant	192·1		101·8	Significant	297·0	

Conclusions —

20N 20N 10N 10N 20N No 20N 20N 10N 20N No 10N 20N 20N 20N 10N 10N No
20P 10P 10P 10P M. 20P 10P 10P 10P M. 20P 10P 10P 10P M

Treatments	Ganeshpur village, Waraseoni Soil.—Sihar (sandy loam). light				Richhai farm, Jubbulpore Sandy soil, *Sehra*							
	1939				1938				1939			
	Variety.— R10 Chhatri				*Variety.—R13 Chhatri*				*Variety.—R6 Budhiabako*			
(Per acre)	Lb.	Lb.		Rs. a.	Lb.	Lb.		Rs. a.	Lb.	Lb.		Rs. a.
0 lb. N + 0 lb. P_2O_5	568	..	..	..	1,197	..	..	..	526	..	..	..
0 lb. N + 10 lb. P_2O_5	701	133	23	1 0	1,455	258	22	3 13	761	235	45	2 12
0 lb. N + 20 lb. P_2O_5	897	329	57	3 7	1,362	165	14	—0 3	706	180	34	—0 4
10 lb. N + 0 lb. P_2O_5	686	118	21	—0 4	1,377	180	15	1 2	898	372	71	4 9
10 lb. N + 10 lb. P_2O_5	975	407	72	4 4	1,695	498	42	6 4	978	452	83	4 4
10 lb. N + 20 lb. P_2O_5	933	365	64	1 6	1,533	336	28	0 11	834	308	59	—0 9
20 lb. N + 0 lb. P_2O_5	941	373	66	2 8	1,326	129	11	—2 15	1,074	548	62	5 2
20 lb. N + 10 lb. P_2O_5	1,124	556	98	4 10	1,755	558	47	4 10	809	283	54	—2 1
20 lb. N + 20 lb. P_2O_5	938	370	65	—1 7	1,659	462	39	0 9	1,181	655	125	3 7
	S. E. of Tr. mean	'Z' test P=0·01	Cr. diff. P=0·05		S. E. of Tr. mean	'Z' test P=0·05	Cr. diff. P=0·05		S. E. of Tr. mean	'Z' test P=0·01	Cr. diff. P=0·05	
	98·5	Significant	273·3		114·5	Significant	330·9		122·2	Significant	338·8	

Conclusions —

20N 10N 20N 20N 10N 20P 10P 10N No 20N 10N 20N 10N 10P 10N 20P 20N No 20N 20N 10N 10N 10N 20N 10P 20P No
10P 10P 20P 20P M. 10P 10P 20P 20P M. 20P 10P 20P 10P M.

* At pre-war prices.

(5) Organic nitrogen, 20 lb. per acre.
(6) Inorganic nitrogen 5 lb. + Organic nitrogen 5 lb. per acre.
(7) Inorganic nitrogen 10 lb. + Organic nitrogen 10 lb. per acre.

The experimental field was *rabi* land diverted to paddy, in block V of Labhandi farm and the soil was heavy *Dorsa* (clay loam). The ultimate size of the plot was 1/50th acre ($13\frac{3}{4}$ft × $63\frac{1}{4}$ft.) with $1\frac{1}{3}$ ft. as non-experimental margin. The variety was R6 Budhiabako (late) and the method of cultivation was *biasi*. Farmyard manure was applied before the sowing of seed in June and fertilizers were applied two weeks after *biasi*. The crop was irrigated and the rotation every year was rice after rice.

Table V

Effect of organic and inorganic manures and their mixtures on the yield of paddy
Combined results of five years, 1939 to 1943
Soil.—Heavy Dorsa *(clay loam).* Rabi *land diverted to paddy*

Treatments	Average yield (five years) in lb.	Increase over no manure in lb.	Percentage of increase over no manure	At pre-war prices, August 1939			At rates prevailing in December 1943		
				Value of extra yield	Cost of manure	Profit	Value of extra yield	Cost of manure	Profit
(Per acre)	Per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
No manure	648	..	..	..	..	..	..	..	..
Farmyard manure 10 lb. N	875	227	35	4 9	1 9	3 0	15 2	3 2	12 0
Farmyard manure 20 lb. N	1,017	369	57	7 6	3 2	4 4	24 10	6 4	18 6
Farmyard manure 5 lb. N + Ammonium sulphate 5 lb. N	1,060	412	64	8 4	2 4	6 0	27 7	4 10	22 13
Farmyard manure 10 lb. N + Ammonium sulphate 10 lb. N.	1,215	567	87	11 5	4 8	6 13	37 13	9 4	28 9
Ammonium sulphate 10 lb. N	1,076	428	66	8 9	2 15	5 10	28 9	6 2	22 7
Ammonium sulphate 20 lb. N	1,323	675	104	13 8	5 13	7 11 Cr. Diff. Rs. 2-13-0	45 0	12 4	32 12 Cr. Diff. Rs. 9-6-3

S. E. of Tr. mean = 48·28 ‘Z’ test (P = 0·01) Significant Cr. Diff. (P = 0·05) = 140·9

Conclusions—

NH4SO4—20 lb. N NH4SO4—10 lb. N F.Y.M. 10 lb. N NH4SO4—10 lb. N. NH4SO4—5 lb. N F.Y.M. 5 lb. N F.Y.M.—20 lb. N > F.Y.M.—10 lb. N 7 No manure

Pre-war prices, August 1939.—Farmyard manure at Re. 1 per cart of 800 lb. Nitrogen in air dry sample = 0·8 per cent.
Rates prevailing in December 1943.—Farmyard manure at Rs. 2 per cart of 800 lb.

The results show that on heavy soils (*Dorsa*, clay loam) nitrogenous fertilizers alone, or a mixture of organic and inorganic nitrogen gives significantly higher yield than farmyard manure applied on the same nitrogen basis. The average yield per acre of plots receiving 100 lb. ammonium sulphate (20 lb. N.) was 1,323 lb. and of those supplied with a mixture of 10 lb. nitrogen as farmyard manure with 10 lb. nitrogen as ammonium sulphate, 1,215 lb., against 1,017 lb. of plots receiving 20 lb. nitrogen as farmyard manure.

20 lb. nitrogen per acre applied as farmyard manure gave the same yield as 10 lb. nitrogen supplied as ammonium sulphate, or a mixture of 5 lb. organic and 5 lb. inorganic nitrogen.

The need for a dressing of nitrogenous fertilizers is clearly indicated.

Experiment 3.—Effect of different quantities of nitrogen applied in the form of compost on the yield of paddy

The experiment was laid out in randomized blocks with six replications on two different soils at Labhandi farm, Raipur. The treatments were 0, 20, 40 and 60 lb. nitrogen per acre in the form of compost (nitrogen in air dry sample 0·5 per cent). The ultimate size of the plot was 1/80th acre ($18\frac{1}{2}$ ft. × $29\frac{1}{2}$ ft.) with $1\frac{3}{4}$ ft. as non-experimental margin. The method of cultivation was *biasi* and compost was applied before the sowing of seed. The variety was R6 Budhiabako (late) and the crop was irrigated. Rotation every year was rice after rice.

TABLE VI

Effect of different quantities of nitrogen applied in the form of compost on the yield of paddy
Combined results of three years, 1942 to 1944

Treatments	Average yield (three yrs.) in lb.	Increase over no manure in lb.	At pre-war prices, August 1939: Percentage of increase over no manure	At pre-war prices, August 1939: Value of extra yield	At pre-war prices, August 1939: Cost of manure	At pre-war prices, August 1939: Profit	At rates prevailing in December 1943: Value of extra yield	At rates prevailing in December 1943: Cost of manure	At rates prevailing in December 1943: Profit
(Per acre)	per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
			Soil.—Matasi (sandy loam)						
No manure	921	..	..	..	..	..	..	..	..
Compost 20 lb. N	1,173	252	27	5 1	2 8	2 9	16 13	5 0	11 13
Compost 40 lb. N	1,352	431	47	8 10	5 0	8 10	28 12	10 0	18 12
Compost 60 lb. N	1,549	628	68	12 9	7 8	5 1 Cr. Diff. Rs. 2-1-0	41 14	15 0	26 14 Cr. Diff. Rs. 6-14-3

S.E. of tr. mean = 34·32 'Z' test.—Significant at 1 per cent Cr. Diff. (P = 0·05) = 103·36

Conclusions.—N 60 > N 40 > N 20 > No manure

Soil.—Dorsa (clay loam)

Treatments	Average yield (three yrs.) in lb.	Increase over no manure in lb.	At pre-war prices, August 1939: Percentage of increase over no manure	At pre-war prices, August 1939: Value of extra yield	At pre-war prices, August 1939: Cost of manure	At pre-war prices, August 1939: Profit	At rates prevailing in December 1943: Value of extra yield	At rates prevailing in December 1943: Cost of manure	At rates prevailing in December 1943: Profit
No manure	968	..	..	..	..	..	..	..	..
Compost 20 lb. N	1,129	161	17	8 4	2 8	0 12	10 12	5 0	5 12
Compost 40 lb. N	1,383	415	43	8 5	5 0	3 5	27 11	10 0	17 11
Compost 60 lb N	1,550	582	60	11 10	7 8	4 2 Cr. Diff. Rs. 2-15-0	38 13	15 0	23 13 Cr. Diff. Rs. 9-12-6

S. E. of tr. mean = 48·72 'Z' test.—Significant at 1 per cent Cr. Diff. (P = 0·05) = 146·84

Conclusions.—N 60 > N 40 > N 20 > No manure

of Pre-war prices, August 1939.—Compost made of vegetable waste matter with a small amount of cowdung as a 'starter' at as. 8 per cart 80 lb. (Nitrogen in air dry sample = 0·5 per cent)
Rates prevailing in December 1943.—Compost at Re. 1 per cart

On light soil (*Matasi*) the application of 60 lb. nitrogen in the form of compost increased the yield of paddy from 921 lb. to 1,549 lb. per acre, an increase of 68 per cent ; 40 lb. nitrogen increased the yield to 1,352 lb., an increase of 47 per cent and 20 lb. nitrogen increased it to 1,173 lb., an increase of 27 per cent. The net profits were all statistically significant.

Similar results were obtained on heavy soil (*Dorsa*), but the effect of 20 lb. nitrogen in the form of compost was less pronounced.

Experiment 4. Effect of different quantities of nitrogen applied in the form of oil-cakes on the yield of paddy

The experiment comprising a study of the effects of groundnut, linseed and sesamum (*til*) cakes, each applied at 0, 20, 40 and 60 lb. nitrogen per acre on the yield of paddy was laid out in six randomized blocks, each having 12 plots. There were three unmanured plots in each block thus giving only 10 different treatments. The soils were sandy loam (*Matasi*) and clay loam (*Dorsa*) at Labhandi farm, Raipur. The ultimate size of the plot was 1/80th acre ($18\frac{1}{2}$ ft. × $29\frac{1}{2}$ ft.) with $1\frac{3}{4}$ ft. as non-experimental margin. The method of cultivation was *biasi* and oil-cakes were applied at the time of sowing of seed. The variety was R6 Budhiabako (late) and the crop was irrigated. Rotation every year was rice after rice.

TABLE VII

Effect of different quantities of nitrogen applied in the form of oilcakes on the yield of paddy
Combined results of three years, 1942 to 1944

Treatments	Average yield (3 years) in lb.	Increase over no manure in lb.	At rates prevailing in December 1943*			
			Percentage of increase over no manure	Value of extra yield	Cost of manure	Profit or loss
(Per acre)	per acre			Rs. a.	Rs. a.	Rs. a.
			Soil.—Matasi (*sandy loam*)			
No manure	1,079	..	..	..	..	..
Groundnut cake—						
20 lb. N.	1,342	263	24	17 9	14 0	3 9
40 lb. N.	1,714	635	59	42 5	28 0	14 5
60 lb. N.	2,030	951	88	63 6	42 0	21 6
Linseed cake—						
20 lb. N.	1,410	331	31	22 1	25 12	—3 11
40 lb. N.	1,685	606	56	40 6	51 8	—11 2
60 lb. N.	2,076	997	92	66 7	77 4	—10 13
Til cake—						
20 lb. N.	1,382	303	28	20 3	17 12	2 7
40 lb. N.	1,821	742	69	49 7	35 8	15 15
60 lb. N.	1,120	1,041	96	69 6	53 4	16 2
		Cr. diff.	(P=0·05) 157·9	Cr. diff. Rs. 10-8-6		

S. E. of tr. mean 56·96

'Z' test

Quality of nitrogen—Significant at 5 per cent
Quantity of nitrogen—Significant at 1 per cent
Interactions—
Quality × Quantity.—Insignificant
Quality × Season—Insignificant
Quantity × Season—Insignificant
Treatments.—Significant at 1 per cent

* Rates prevailing in December 1943.—Groundnut cake (7 per cent nitrogen) at Rs. 4 per maund. Linseed cake at (4·5 per cent N.) at Rs. 4-12-0 per maund. *Til* cake (5·2 per cent N.) at Rs. 3-12-6 per maund. Buddhiabako paddy 15 lb. per rupee

Quality of nitrogen

Mean yield of all the plots receiving groundnut cake—1,695 lb. per acre
Mean yield of all the plots receiving linseed cake—1,724 lb. per acre
Mean yield of all the plots receiving *til* cake—1,812 lb. per acre
Cr. diff. = 91·15 lb. per acre

Conclusions—Til cake Linseed cake Groundnut cake

Quantity of nitrogen and *treatments*:
Conclusions (in order of yield):

T. N. 60, L.N. 60, G. N. 60>T.N. 40, G.N. 40, L.N. 40>L.N. 20, T.N. 20, G. N. 20>No manure

Treatments	Average yield (3 years) in lb.	Increase over no manure in lb.	Percentage of increase over no manure	At rates prevailing in December 1943: Value of extra yield	Cost of manure	Profit or loss
(Per acre)	per acre			Rs a.	Rs. a.	Rs. a.
		Soil.—Dorsa (*clay loam*)				
No manure	1,067	..	..	..	..	..
Groundnut cake—						
20 lb. N.	1,361	294	28	19 10	14 0	5 10
40 lb. N.	1,693	626	59	41 12	28 0	13 12
60 lb. N.	2,015	948	89	63 3	42 0	21 3
Linseed cake—						
20 lb. N.	1,615	548	51	36 9	25 12	10 13
40 lb. N.	1,893	826	77	55 1	51 8	3 9
60 lb. N.	2,138	1,071	100	71 6	77 4	-5 14
Til cake—						
20 lb. N.	1,327	260	24	17 5	17 12	-0 7
40 lb. N.	1,839	772	72	51 7	35 8	15 15
60 lb. N.	2,187	1,120	105	74 11	53 4	21 7
			Cr. diff. (P=0·05) 146·6			Cr. diff. Rs. 11-4-3

S. E. of tr. mean 60·98

'Z' test

Quality of nitrogen—Significant at 1 per cent
Quanity of nitrogen—Significant at 1 per cent
Seasons—Significant at 1 per cent
Interactions—
Quality × Quantity—Insignificant
Season × Quality—Significant at 1 per cent
Season × Quantity—Significant at 5 per cent
Treatments—Significant at 1 per cent

Quality of nitrogen

Mean yield of all the plots receiving groundnut cake—1,689 lb. per acre
Mean yield of all the plots receiving linseed cake—1,882 lb. per acre
Mean yield of all the plots receiving *til* cake—1,784 lb. per acre
Cr. diff. = 84·58 lb. per acre

Conclusions.—Linseed cake > *Til* cake > Groundnut cake

Quanity of nitrogen

Mean yield of 60 lb. nitrogen in all the plots receiving groundnut, linseed and *til* cake—2,113 lb. per acre
Mean yield of 40 lb. nitrogen in all the plots receiving groundnut, linseed, and *til* cake—1,808 lb. per acre
Mean yield of 20 lb. nitrogen in all the plots receiving groundnut, linseed and *til* cake—1,434 lb. per acre
Mean yield of 0 lb. nitrogen in all the plots receiving groundnut, linseed and *til* cake (No. manure)—1,067 lb. per acre
Cr. diff. = 84·58 lb. per acre

Conclusions—60 lb. N > 40 lb. N > 20 lb. N > No manure

Seasons

Mean yield of all the plots during 1942 = 1,402 lb. per acre
Mean yield of all the plots during 1943 = 1,515 lb. per acre
Mean yield of all the plots during 1944 = 1,899 lb. per acre
Cr. diff. = 73·3 lb. per acre

Conclusions—1944 > 1943 > 1942

Season × quality of nitrogen

Differences in yeilds in lb. per acre

Oil-cakes	Season 1942	Season 1943	Season 1944
Linseed minus *til* cake	—29	175	148
Linseed minus groundnut	168	358	50
Til minus groundnut cake	197	183	—98

Cr. diff.=146·6

In 1942 season, the application of *til* or linseed cake has given significantly higher yield than groundnut cake ; the difference between *til* and linseed cake being insignificant.

In 1943, linseed cake is significantly better than *til* cake and *til* cake significantly better than groundnut cake.

In 1944, again, linseed cake is significantly better than *til* cake, but the differences between linseed and groundnut cake or groundnut and *til* cake are not significant.

In the combined results of all the three years, linseed cake is significantly better than *til* cake and *til* cake significantly better than groundnut cake.

Season × quantity of nitrogen

Differences in yields in lb. per acre

Season	Quantity of ntrogen 60 lb. N	40 lb. N	20 lb. N	0 lb. N
1944 minus 1943	372	359	434	369
1943 minus 1942	177	200	2	77
1944 minus 1942	549	559	436	446

Cr. diff.=146·6.

Differences in yields between no manure plots of 1942 and 1943, and also between plots receiving 20 lb. nitrogen in the same two years are not statistically significant.

With higher dose of nitrogen difference in yield between one season and the other is significant.

Treatments

Conclusions.—(In order of yield)

T. N. 60, L. N. 60, G. N. 60, L. N. 40 T. N. 40, G. N. 40, L. N. 20. > G. N. 20, T. N. 20 > No Manure

At pre-war prices it was not profitable to manure paddy with the above oil-cakes

On light soil (*Matasi*) the application of 60 lb. nitrogen in the form of groundnut cake ($10\frac{1}{2}$ maunds) increased the yield of paddy from 1,079 lb. to 2,030 lb. per acre, an increase of 88 per cent and gave a net profit of Rs. 21-6-0 at the present prices. 40 lb. nitrogen in the form of groundnut cake (7 maunds) increased the yield to 1,714 lb. per acre (59 per cent) and gave a net profit of Rs. 14-5-0.

Til cake sufficient to supply 60 lb. nitrogen (14 maunds) increased the yield of paddy from 1,079 lb. to 2,120 lb. per acre (96 per cent) and gave a net profit of Rs. 16-2-0. 40 lb. nitrogen in the form of *til* cake (9 maunds) increased the yield to 1,821 lb. per acre (69 per cent) and gave a net profit of Rs. 13-15-0.

On account of high price and low nitrogen content of linseed cake it was not profitable to apply it.

On heavy soil (*Dorsa*) the application of 60 lb. nitrogen in the form of *til* cake increased the yield of paddy from 1,067 lb. to 2,187 lb. per acre, an increase of 105 per cent and gave a net profit of

Rs. 21-7-0. 40 lb. nitrogen in the form of *til* cake increased the yield to 1,839 lb. per acre (72 per cent) and gave a net profit of Rs. 15-15-0.

A dressing of 60 lb. nitrogen in the form of groundnut cake increased the yield of paddy from 1,067 lb. to 2,015 lb. per acre (89 per cent) and gave a net profit of Rs. 21-3-0. 40 nitrogen in the form of groundnut cake increased the yield to 1,693 lb. per care (59 per cent) and gave a net profit of Rs. 13-12-0
(Plate XVII).

Summary

Manurial experiments were carried out at the Rice Research Station Raipur from 1935 to 1943, with the object of ascertaining the effect of (1) fertilizers, (2) organic and inorganic manures and their mixtures, (3) compost and (4) oil-cakes on the yield of paddy.

Fertilizer experiments conducted at the Rice Research Station, Raipur for five years, on light (sandy loam) as well as heavy (clay loam) soils have shown that highest yield and largest net profit are obtained only when nitrogenous and phosphatic fertilizers are given in combination. The most effective nitrogen and phosphate ratio is 1 : 1. The application of 20 lb. nitrogen in the form of ammonium sulphate with 20 lb. phosphoric acid in the form of double superphosphate per acre has given significantly higher yield than either 20 lb. nitrogen or 20 lb. phosphoric acid applied alone. Individually, 20 lb. nitrogen is significantly better than 20 lb. phosphoric acid, and 20 lb. phosphoric acid significantly better than no manure.

The application of 20 lb. nitrogen with 20 lb. phosphoric acid (100 lb. ammonium sulphate with 50 lb double superphosphate) increased the yield of late paddy from 988 lb. to 2,122 lb. per acre, an increase of 115 per cent, and gave a net profit of Rs. 12-15-0 at pre-war rates and Rs. 51-10-0 at the present prices. If the cultivators are not able to use this quantity of fertilizers (costing Rs. 9-12-0 at pre-war rates and Rs. 21 at the present prices) a dressing of at least 50 lb. ammonium sulphate with 25 lb. double superphosphate per acre is recommended. This application of fertilizers will increase the yield, on an average, by 50 per cent and will be definitely profitable. Simplified experiments laid out on cultivators' holdings in 23 important rice, producing tahsils confirmed the above results.

On very light (sandy) soils, phosphoric acid is the limiting factor. The application of 20 lb. P_2O_5 (50 lb. double superphosphate) per acre increased the yield of paddy from 879 lb. to 1,326 lb., an increase of 51 per cent, and gave the largest net profit at pre-war rates. Differences in yields due to the application of 20, 30 or 40 lb. phosphoric acid per acre were, however, not significant.

Very light soils do not respond to the application of nitrogen alone, even to the extent of 40 lb. per acre. The application of nitrogenous fertilizers is, therefore, accompanied with loss. But a combination of nitrogenous and phosphatic fertilizers is very effective in bringing about significant increase in yield over phosphates applied alone or over no manure. On these soils also the most effective nitrogen and phosphate ratio is 1 : 1. The application of 20 lb. nitrogen with 20 lb. phosphoric acid increased the yield of paddy from 879 lb. to 1,582 lb. per acre, an increase of 80 per cent and was profitable.

The application of nitrogenous fertilizers alone, or a mixture of organic and inorganic nitrogen gives significantly higher yield than farmyard manure applied on the same nitrogen basis. The average yield per acre of plots receiving 100 lb. ammonium sulphate (20 lb. N.) was 1,323 lb. and of those supplied with a mixture of 10 lb. nitrogen as farmyard manure with 10 lb. nitrogen as ammonium sulphate, 1,215 lb., against 1,017 lb. of plots receiving 20 lb. nitrogen as farmyard manare. 20 lb. nitrogen per acre applied as farmyard manure gave the same yield as 10 lb. nitrogen supplied as ammonium sulphate, or a mixture of 5 lb. organic and 5 lb. inorganic nitrogen.

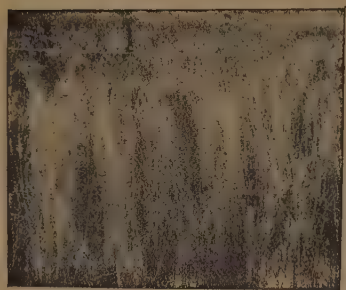
The need for a dressing of nitrogenous fertilizers is, therefore, clearly indicated.

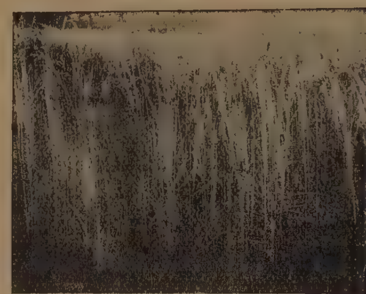
The application of 60 lb. nitrogen in the form of compost (12,000 lb.) increased the yield of paddy from 921 lb. to 1,549 lb. per acre, an increase of 68 per cent and 40 lb. nitrogen in the form of compost (8,000 lb.) increased it to 1,352 lb. per acre, an increase of 47 per cent. The net profits were statistically significant.

EFFECT OF MANURING PADDY WITH GROUNDNUT CAKE

Yield of paddy in lb. per acre

(*Average of 3 years, 1942 to 1944*)





	1079 lb.	1714 lb.	2030 lb.
			
	No manure	7 maunds cake (40 lb. N.)	10½ maunds cake (60 lb. N.)
Increase ..		59%	88%
Extra yield ...		635 lb.	951 lb.
		At rates prevailing in December 1943	
Value at 15 lb. a rupee ...		Rs. 42/5	Rs. 63/6
Cost of manure ...		Rs. 28/0	Rs. 42/0
Profit ...		Rs. 14/5	Rs. 21/6

[Rice Research Scheme, C.P.]

Appendix A

Mechanical and chemical Analyses of Rice Soils on which manurial experiments were conducted*

Locality	Soil	Depth	Per cent air dry soil passed through 1 mm. sieve						Per 100 gm. soil		Percentage Total P_2O_5	Percentage available P_2O_5	Loss on ignition per cent	Carbon per cent	C×1·724	Humus per cent	Organic matter humified per cent	Organic N per cent	C : N ratio	pH value
			Moisture	Loss on ignition	Clay	Fine silt	Coarse silt	Fine sand	Total Ca	Exchangeable Ca										
Labhandi farm. Raipur.	*Matasi*	0in—6 in.	1·07	6·70	25·36	3·7	8·84	58·74	30·5	28·0	·0280	·0141	6·70	·6150	1·060	·206	19·43	·078	7·8	6·8
		6in.—12 in.	2·50	6·09	34·34	3·14	6·78	51·29	17·21	11·55	·540	..	6·09	·5860	1·01	·270	26·73	·08	7·3	7·2
		12in.—18 in.	3·79	8·74	44·79	3·98	7·8	42·67	18·00	17·20	·0342	..	8·74	·4790	0·826	·050	60·56	·072	6·6	7·2
	Dorsa	0in.—6 in.	1·52	3·34	48·26	5·08	7·86	34·86	19·60	19·50	·0321	·0041	3·34	·5750	0·991	·082	8·27	·760	7·5	7·2
		6in.—12 in.	4·35	10·84	50·56	4·36	7·68	32·86	22·00	17·80	·0242	..	10·84	·30	0·517	·062	11·99	·038	7·9	7·4
		12in.—18 in.	4·81	10·34	49·05	4·7	8·63	32·89	34·70	29·99	·0298	..	10·34	·3580	0·617	·036	5·83	·040	8·9	7·4

*Report on the soil-work carried out under the Central Provinces Rice Research Scheme Raipur, 1942

On light soils, a dressing of 60 lb. nitrogen in the form of groundnut cake (10½ maunds) increased the yield of paddy from 1,079 lb. to 2,030 lb. per acre, an increase of 88 per cent, and gave a net profit of Rs. 21 at the present prices. 40 lb. nitrogen in the form of groundnut cake (7 maunds) increased the yield to 1,714 lb. per acre (59 per cent) and gave a net profit of Rs. 14.

On heavy soils, *til* (Sesamum) cake sufficient to supply 60 lb. nitrogen (14 maunds) increased the yield of paddy from 1,067 lb. to 2,187 lb. per acre, an increase of 105 per cent and gave a net profit of Rs. 21. 40 lb. nitrogen in the form of *til* cake (9⅔ maunds) increased the yield to 1,839 lb. per acre (72 per cent) and gave a net profit of Rs. 16.

Cultivators in the rice tract are therefore advised as follows :

(1) Apply 100 lb. ammonium sulphate with 50 lb. double superphosphate (20 lb. N. + 20 lb. P_2O_5) per acre as a top-dressing to paddy in August. This combination of fertilizers will be most profitable.

(2) If it is not possible to use the above quantities of fertilizers, apply at least 50 lb. ammonium sulphate with 25 lb. double superphosphate (10 lb. N. + 10 lb. P_2O_5) per acre.

(3) If superphosphate is not available, apply 100 lb. ammonium sulphate (20 lb. N.) per acre, (except on very light or sandy soils where the application of ammonium sulphate alone will not be profitable).

(4) If the above quantity of ammonium sulphate is not available, even 50 lb. ammonium sulphate (10 lb. N.) per acre can be applied as a top-dressing, preferably after a basal dressing of 1½ carts of farmyard manure (1,250 lb. = 10 lb. N.) per acre.

(5) Prepare compost from waste vegetable matter and apply at the rate of 10 carts (8,000 lb. = 40 lb. N.) per acre.

(6) Apply seven maunds of powdered groundnut cake (40 lb. N.) per acre before transplantation and in *biasi* fields at the time of sowing of seed (1 maund = 82 lb.). On heavier soils, 9⅔ maunds of *til* cake (40 lb. N.) per acre can also be applied.

Acknowledgements

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A NEW COLORIMETRIC METHOD FOR THE DETERMINATION OF STARCH IN LEAVES AND WOODY TISSUES OF PLANTS

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RECENTLY a method [Chinoy, 1941] was described by which starch in plant material was estimated micro-gravimetrically as starch-iodide. The need for a suitable colorimetric method for the determination of minute quantities of starch was stressed in a previous communication [Chinoy, 1939]. The first pre-requisite for the colorimetric determination of starch is to obtain the starch iodide complex in perfectly colloidal form. This was achieved in the above method by adding an adequate quantity of 0·1. N KI to the starch solution and generating iodine gradually by introducing drop by drop a weak solution of H_2O_2. The clear blue color of starch-iodide thus produced was matched against a standard starch solution similarly treated after the removal of excess of iodine by shaking with $CHCl_3$. This method has been successfully tried in the case of soluble starch, pure natural starches, potato tubers, as well as rice and wheat flours. During the course of work in plant physiology a need was felt for investigating the applicability of this colorimetric method to various plant materials. The technique described here appears to be suitable for general application to plant material.

The stability of starch extracts is also important from the point of view of accuracy in its determination. The analytical work will be greatly facilitated if storage of plant extracts without deterioration can be achieved even for a few days. The use of 21 per cent hydrochloric acid in the cold [Rask, 1927] is open to grave objection as appreciable losses of starch take place by hydrolysis within half-an-hour, even if the solution is kept at a low temperature. Pucher and Vickery [1936] have pointed out difficulties and errors in the use of a concentrated solution of calcium chloride for the extraction of starch. The use of 0·7 per cent KOH which was first suggested by Chinoy, Edwards and Nanji [1934] has been observed to be quite suitable. Attempts have been made here to give experimental proof for the observation.

Extraction of starch from plant material has generally presented difficulties in its determination by the methods involving the specific starch-iodide reaction. This is more so when the plant material is fibrous or woody. Sullivan [1935] in his work on woody tissues of plants, has shown that the size of the particles to which the plant material is reduced before extraction considerably affects the efficiency of the extraction and the accuracy of the subsequent determination. This aspect of the problem has also received attention in this work.

Extraction of starch from plant material

After the preliminary treatment of plant material [Chinoy 1938] an aliquot part 0·1 to 0·3 gm. is moistened with 1-2 ml. of 0·7 per cent KOH, transferred a little at a time into the cup of the micro-macerator, ground to a pasty mass and extracted as reported previously [Chinoy, 1945].

Colorimetric determination of starch

The alkali extracts of plant materials are generally pale to dark yellow and sometimes red. This has been shown to be probably due to the presence of pectins and dextrins [Chinoy, 1938]. Such a colour would obviously be a hinderance in the measurement of the blue colour of starch-iodide. The procedure adopted in the case of natural starches, soluble starch, potato tubers and wheat and rice flours [Chinoy, 1939] had to be modified to overcome the above difficulty. Another source of interference that may be anticipated is from substances of the amylohemicellulose type described by Schulze [quoted from Pucher and Vickery, 1936], Schryver and Thomas [1923] and Ling and Nanji [1925] which occur in certain starch bearing seeds, fruits, leaves and stems. These substances give an intense blue or violet colour with iodine but differ from true starch in that they are not digested by Taka-diastase. A modification of the original method is, therefore, necessary to account for these substances if their presence is suspected.

Duplicate aliquots of plant extracts are pipetted out in centrifuge tubes (with tapering ends) and after neutralization of the alkali with the requisite amount of 10 per cent CH_3COOH, 1-2 ml. of 0·1 N iodine and 2-5 ml. of 10 per cent potassium acetate solution are added to precipitate starch-iodide. After standing for an hour or two for coagulation the precipitates are centrifuged for five minutes at 2000 r.p.m. The supernatant clear liquid is siphoned off, and 10 ml. of 30 per cent ethanol are added to the precipitate and, after thorough mixing, it is again centrifuged. After removal of the clear liquid 1 ml. of 0·7 per cent KOH is added to the starch-iodide precipitate and the tube is gently warmed in a water bath (70°-80°C.) for five minutes to remove iodine and gelatinize the starch. On cooling the alkali is neutralized with 10 per cent CH_3COOH and the blue colour of starch iodide is developed by the addition of 1-2 ml. of 0·1 N KI and a requisite amount of dilute (5 volumes) H_2O_2 (about 1 ml.). Standards are prepared as usual by treating a number of aliquots (varying from 1 to 5 ml.) of a standard solution of pure dry rice starch (A.R.) of a known strength with 1-2 ml. of 0·1 N KI and sufficient quantity of H_2O_2 so as to have a slight excess of free iodine in the solution. After allowing the solutions to stand for one hour the excess of iodine is removed by repeated shakings with about 5 ml. of $CHCl_3$. The unknown solutions are then matched against a standard of suitable strength and the starch content as percentage of dry weight of the plant materials is determined by the formula* stated in a previous publication [Chinoy, 1939].

* The formula is reproduced here for ready reference $S = 100 \frac{ALV}{GVR}$ where S represents starch content of the material as percentage of dry weight; A, starch in the aliquot of the Standard Solution; V, total volume of the unknown Solution (plant extract); L, colorimetric reading of the Standard Solution; R, colorimetric reading of the unknown Solution; V, aliquot of the unknown Solution taken for comparison and G, plant material in grammes used for preparing the unknown Solution.

The above procedure not only eliminates the colouring matters of the original extract but it also greatly helps to overcome the difficulty which arises in certain cases where it has been observed that alkali extracts of plant material contain some substances which absorb iodine.

In case the presence of amylohemicelluloses is suspected the following procedure is to be followed. An aliquot of a plant extract is neutralized in the usual manner and 1 ml. of a fresh 1 per cent solution of Taka-diastase is added to it and incubated at 37°C. for 1-2 hours, after which the tube is placed in a boiling water bath for five minutes. The above procedure for colour development is followed after cooling the tube. As all the starch will be hydrolyzed by Taka-diastase the development of blue colour will indicate the presence of amylohemicelluloses. The strength of the blue colour in these tubes treated with Taka-diastase can be calculated out in terms of starch and a correction applied to the quantity found in aliquots which are not treated with Taka-diastase. The former gives the value of amylohemicelluloses and the latter gives the value of starch and amylohemicelluloses. Information available in the literature however, point to the fact that the relative proportion of these compounds is usually very small, and therefore no serious error is likely to arise even if their determination is overlooked.

Starch in leaves with special reference to its stability in KOH solution†

Leaves of four different plants, viz. *Lycopersicum esculantum*, *Brassica rapa*, *Trifolium alexandrianum* and *Medicago denticulata*, were used for these experiments. Out of these four the first two were same (Sample No. II in both the cases) as those used in previous experiments [Chinoy, 1938]. After removal of soluble substance by extraction with alcohol, and desiccation and reduction of the sample to 100 mesh grade starch was extracted and determined according to the technique outlined above, in two separate aliquot parts of each sample and in duplicate for each portion. The results are presented in Table I.

Table I

Starch content of leaves

Standard starch solution. 1·5630 mg. in 1 ml. Total volume of extract. 50 ml. in all cases. KOH gelatinization: aliquots of extracts neutralized with 10 per cent CH_3COOH just before the addition go 2 ml. of 0·1 N KI + 1-2 ml. of dilute (5 volumes) H_2O_2.

Treatment No.	Plant material	Sample analysed gm.	Standard solution ml.	Extract ml.	Colorimetric ratio	Starch percentage (dryweight)
1	*Lycopersicum esculantum* (Tomato leaf No. II—(Chinoy, 1938)	0·2830	1	5	0·9035	5·00
1a	Ditto	0·2830	1	7	1·2820	5·06
2	Ditto	0·2631	1	5	0·8790	5·22
2a	Ditto	0·2631	2	10	0·8835	5·25
3	*Trifolium Alexandrianum* . . .	0·2161	1	5	0·9980	7·22
3a	Ditto	0·2161	2	10	0·9560	6·91
4	Ditto	0·3931	2	5	0·8775	6·98
4a	Ditto	0·3931	2	5	0·8910	7·09
5	*Brassica rapa* (Raddish leaf No. II)—(Chinoy, 1938)	0·2611	1	5	1·0440	6·25
5a	Ditto	0·2611	2	10	0·9420	5·64
6	Ditto	0·2101	1	5	0·9080	6·75
6a	Ditto	0·2101	2	10	0·8955	6·66
7	*Medicago denticulata* . . .	0·3551	2	5	0·8750	7·70
7a	Ditto	0·3551	2	5	0·8890	7·83
8	Ditto	0·2005	1	5	1·0350	8·07
8a	Ditto	0·2005	2	10	1·0030	7·82

This may be numbered part III of the series of which parts I and II appeared elsewhere [Chinoy 1939].

Agreement between the duplicates of the same sample is good. Even separate aliquots vary within 1 to 5 per cent. In treatment No. 5a some error appears to have been made in the colorimetric reading. Close agreement between starch contents of separate aliquots of the same sample suggests that it becomes quite homogeneous if passed through a 100-mesh sieve.

As already stated storage of plant extracts without deterioration will greatly facilitate work. Starch is known to be fairly stable in an alkaline medium. As no data on the stability of starch under the conditions of these experiments was available, it appeared of interest to study this question. Plant extracts used for determinations of starch in Table I were stored in well stoppered glass bottles without neutralization of alkali and aliquots were removed from them at different intervals of time, neutralized and starch estimated as usual. Four such determinations were made at intervals of 4, 8, 15 and 25 days respectively after storage. Results appear in Table II.

Table II

Starch content of the same extracts as shown in Table I after storage—

Standard starch solutions : 1·5630, 1·372, 1·430 and 1·3823 mg. per 1 ml. in 4, 8, 15 and 25 days storage sets respectively (fresh solutions except in the first set).

Total volume of the extract : 50 ml.

KOH gelatinization: aliquots of extracts neutralized with 10 per cent CH_3COOH just before the addition of 2 ml. of 0·1 N KI + 1-2 ml. of dilute (5 volumes) H_2O_2.

Starch content determined after storage for:

Treat-ment No. (Table I)	Standard Solution (ml.)	Ex-tract (ml.)	4 days		8 days		15 days		25 days	
			Colori-metric Ratio	Starch percent-age (dry wt.)	Colori-metric Ratio	Starch per cent age (dry wt.)	Colri-metric Ratio	Starch percent age (dry wt.)	Colori-metric Ratio	Starch percent-age (dry wt.)
1	1	5	0·8856	4·89	1·0300	5·00	0·9110	4·61	0·8030	3·93
2	1	5	·8785	5·22	0·9990	5·21	0·8670	4·71	0·7590	4·00
3	1	5	0·9885	7·15	1·1220	7·12	0·9940	6·58	0·9130	5·84
4	2	5	0·8760	6·97	1·0050	7·02	0·8630	6·28	0·7570	5·32
5	1	5	1·0420	6·24	1·1820	6·20	1·1120	6·08	0·9420	5·00
6	1	5	0·9375	6·97	1·0620	6·92	0·9490	6·47	0·8260	5·45
7	2	5	0·8795	7·74	0·9985	7·71	0·8925	7·18	0·7790	6·06
8	1	5	1·0370	8·08	1·1670	7·97	1·0600	7·56	0·8855	6·11

It will be observed that there is very little deterioration of starch till the 15th day. The values are however slightly lower in most cases suggesting that degradation of starch has just begun. After 25 days of storage there is a definite decline in the values of starch. There is an indication that the losses are some what proportional to the concentration of starch in the alkali solution. The greater the concentration of starch, the greater is the loss in a given time.

Effect of size of particle on the determination of starch content of woody tissues

Terminal shoots of *Bombax malbaricum*, *Ficus religiosa*, and *Mengifera indica* were collected in the month of February (about two months before flowering). After the usual preliminary treatment the dried sample was powdered to pass through a 40-mesh sieve. One third portion of this sample was taken out and the remainder of the sample was further reduced till the whole of it passed through a 60-mesh sieve. It was then again divided (after thorough mixing) into two parts. One of them was stored for starch extractions and the other was further reduced to pass through a 100-mesh sieve. In this manner three grades of powders were obtained from each plant sample. Although the 40-and 60-mesh portions contained particles smaller than its own grade a 100-mesh sample did not contain any particles of these two grades. Aliquots of these graded samples were then crushed to a pasty mass by the technique described elsewhere [Chinoy 1945] and starch was estimated colorimetrically as shown above. The results are presented in Table III.

Statistical analysis of results

Analysis of variance [Fisher 1939] were carried out on data presented in Tables I, II and III in order—(1) to obtain a correct estimate of errors of determination, (2) to determine the period beyond which storage of alkaline starch solutions caused significant reduction in starch content due to its deterioration and (3) to determine size of the sieve mesh which significantly reduced the accuracy of starch determination. Results are presented below (Table IV to VIII).

TABLE III

Effect of particle size on determination of starch in woody tissues

Standard starch solutions : (1) 2·722 mg. per 1 ml. and, (2) 1·364 mg. per 1 ml.

Total volume of the extract : 50 ml. in all cases—

KOH gelatinization : Aliquots of extracts neutralized with 10 per cent CH_3COOH just before the addition of 2 ml. of 0·1 N KI + 1-2 ml. of dilute (5 volumes) H_2O_2.

Plant Material	Plant samples passed through sieve of														
	100-mesh					60-mesh					40-mesh				
	Sample analyzed in gm.	Standard solution in ml.	Extract in ml.	Colorimetric ratio	Starch percentage (dry wt.)	Sample analyzed in gm.	Standard solution in ml.	Extract in ml.	Colorimetric ratio	Starch percentage (dry wt.)	Sample analyzed in gm.	Standard solution in ml.	Extract in ml.	Colorimetric ratio	Starch percentage (dry wt.)
Ficus religiosa—terminal shoots.	0·1713	1 (2)*	5	1·0545	8·39	0·1821	1 (2)*	5	1·0460	7·83	0·1561	1 (2)*	5	1·0460	9·14
,, ,, ,, ,,	0·2387	2 (2)	5	0·7590	8·67	0·7672	2 (2)	5	0·8250	8·42	0·2103	1 (2)	5	1·1070	7·18
Bombax malbaricum—terminal shoots.	0·2401	1 (1)	5	0·8070	9·15	0·1840	1 (1)	10	1·1470	8·48	0·2621	1(1)	5	0·8365	8·69
,, ,, ,, ,,	0·2401	1 (1)	5	0·7920	8·98	0·1840	1 (1)	10	1·0940	8·09	0·2621	1 (1)	10	1·6460	8·55
,, ,, ,, ,,	..	..	..	..	..	0·2160	1 (1)	10	1·1070	6·97	0·1823	1 (1)	10	0·9070	6·77
,, ,, ,, ,,	..	..	..	..	..	0·2160	1 (1)	10	1·0780	6·79	0·1823	1 (1)	10	0·9030	6·74
Mengifera Indica—terminal shoots.	0·1701	1 (1)	5	0·8380	13·41	0·2541	1 (1)	5	1·3215	14·16	0·3221	1 (1)	5	1·1090	9·37
,, ,, ,, ,,	0·1701	1 (1)	5	0·8160	13·06	0·2541	1 (1)	5	1·2760	13·67	0·3221	1 (1)	5	1·0980	9·28
,, ,, ,, ,,	..	..	..	..	..	0·1731	2 (2)	5	0·8180	12·89	0·2012	2 (2)	5	1·0350	13·41

*Figure in parenthesis indicates the number of the Standard solution.

TABLE IV

Analysis of variance of data in Table I—

Mean starch content=6·59 per cent dry wt.

Factor	Degrees of freedom	Sum of square	Mean square	Treatment variance / Error variance	Value of F ($p=0·01$)
Plant material	3	16·03	5·340	87·54	6·99
Experiments	3	0·38	0·127	2·08	6·99
Error	9	0·55	0·061	..	..
TOTAL	15	16·96	..	..	..

S. E. of experiments 0·178.

The ratio of variance of experiments and error variance is not significant. It therefore follows that variations between different determinations are errors of sampling. The standard error is 2·7 per cent of the general mean. There are highly significant differences in starch contents of different plant materials.

TABLE V

Analysis of variance of data presented in Table II—

Mean starch content=6·26 per cent dry wt.

Eight readings for starch content of fresh solutions corresponding to values for four other storage imes have been obtained by taking the average values for eight treatment numbers of Table I.

Factor	Degrees of freedom	Sum of square	Mean square	Treatment variance / Error variance	Value of F ($p=0·01$)
Plant material (P)	3	37·15	12·380	154·75	4·94
Time of storage (T)	4	11·49	2·870	35·87	4·43
Interaction P×T	12	1·20	0·100	1·43	..
Error	20	1·43	0·015	..	..
TOTAL	39	51·27	..	..	..

TABLE VI

The standard in this case is the mean starch content of fresh plant extracts from Table I (6·59 per cent dry wt.)

Time of storage	Mean starch content (per cent dry wt.)	Mean percentage of standard
0	6·590 (Standard) (Table I)	100·0±1·435
4	6·660	101·0±1·435
8	6·645	100·8±1·435
15	6·190	93·6±1·435
25	5·215	79·0±1·435

There is a highly significant effect of storage time. Starch contents of different plant materials vary significantly. S.E. of mean for storage time works out to be 0·0946 which is the mean of values given in Table I and which has been taken as the standard.

For further clarification the mean starch contents for different storage times have been expressed as percentages of the standard treatment.

The standard error of each mean expressed as a percentage of the standard is 1·435 per cent. The standard error of the difference between any two means is 2·03 per cent. A difference between the percentage values greater than 4·23 (C.D.) is therefore significant. It will be seen from Table VI that only after 15 days storage of plant extracts a significant lowering of starch content takes place. No deterioration is observed even after storage for eight days. Starch is therefore very stable in an alkaline solution.

TABLE VII

Analysis of variance of data presented in Table III

Mean starch content = 9·7 per cent dry wt.

Factor	Degrees of freedom	Sum of square	Mean square	Treatment variance / Error variance	Value of F ($p=0{\cdot}01$)
Plant Material (P)	2	55·42	27·71	98·4	8·02
Sieves (S)	2	9·363	4·682	16·58	8·02
Interaction P × S	4	15·892	3·973	14·07	6·62
Error	9	2·535	0·282	..	..
TOTAL	17	83·21	..	..	..

Highly significant differences are obtained for plant material. Sieve and their interaction. As the interaction is significant it appears that the relative hardness of the material will also affect the size and shape of particles passing through a sieve of certain mesh and consequently will influence the accuracy of starch determination. This has also been pointed out elsewhere [Chinoy 1942].

Mean starch contents for different sieve mesh have been presented in Table VIII as percentages of the standard treatment which is in this case the mean starch content of samples screened through a 100-mesh sieve.

TABLE VIII

Sieve	Mean starch content (percentage dry wt.)	Starch content (percentage of standard)
100-mesh	10·28 (Standard)	100·1±2·11
60-mesh	10·11	98·5±2·11
40-mesh	8·70	84·5±2·11

Standard error of each mean expressed as percentage of the standard is 2·11. The standard error of difference of any two means is 2·99. A difference between percentage values greater than 6·79 (C.D.) is therefore significant. Results of starch content are therefore significantly low for samples screened through 40-mesh sieve.

It is clear that the grade to which the material is initially reduced has considerable influence on the accuracy with which starch can be determined. In 100-mesh samples the error of separate determinations is within 3 per cent [also see Chinoy, 1938 and 1941]. Error in starch determination sharply increases with the coarseness of the powder.

Discussion of the results

The new colorimetric method involving the use of 0·1 N KI and dilute H_2O_2 for the development of starch iodide colour gives satisfactory results in the case of leaf material and woody tissues of plants (Tables I and III). Although the use of the micro-macerator [Chinoy, 1945] for reducing the plant material has considerably facilitated extraction work, the accuracy of a starch determination depends upon the size of particles in a sample. The results (Table III) showing the influence of particle size on starch content are substantially in agreement with those of Sullivan [1935]. They clearly demonstrate the fact that in all analytical work of value the sample must be reduced to pass through a 100-mesh sieve before reliable results can be obtained. The disintegration of the plant material by the micro-macerator combined with the macerating action of alkali removes even the last traces of starch from the hardest of plant parts.

The results in Table II leave no room for doubt regarding the stability of starch in alkaline solution at least for about two weeks. This fact gives a considerable advantage to this method over other methods for starch extraction using concentrated $CaCl_2$ and 21 per cent HCl as solvents [Rask, 1927 and Pucher and Vickery, 1936].

The stability and the specificity of the blue starch-iodide colour have already been established in previous communications [Chinoy, 1939] and therefore a determination by this method gives the value of 'true' starch.

Interference in the above blue reaction by amylohemicelluloses is rarely met with and the procedure described here can effectively meet it if necessary.

Summary

1. A new colorimetric method for the determination of minute quantities of starch in leaves and woody tissues is described, where the starch-iodide colour is developed by the addition of KI and H_2O_2 in requisite quantities to generate a slight excess of free iodine.

The colour of starch-iodide is matched in a colorimeter against that of a standard starch solution similarly treated after removal of excess of iodine by chloroform.

2. Data have been presented to show the stability of starch in 0·7 per cent KOH solution. Starch solutions can be stored for about a fortnight without deterioration.

3. Size of particles in a plant sample considerably influences the accuracy of starch determination. For accurate analytical work the sample must be reduced to pass through a 100-mesh sieve.

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AN APPLICATION OF DISCRIMINANT FUNCTION FOR SELECTION IN *DURUM* WHEATS*

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SELECTION for high yield in cereals is one of the chief considerations in plant breeding programme, though there are characters like resistance to diseases or grain quality in wheat which are also important.

Yield in wheat depends upon the number of tillers and ears per plant, number of grains per ear, and weight of grain (usually estimated as weight of 100 grains). A high yielding variety, therefore, should have large number of tillers and ears per plant, more grains per ear and high grain weight, but since the observed variability of the individual characters may be partly genetic and partly environmental, and since characters like the mean number of tillers and ears per plant, and number of grains per ear are highly affected by environmental conditions, plant selections made in the fields on the basis of such observable characters, which are subject to a large non-heritable variability, may not be efficient. It has, therefore, been suggested that, first, the selection for high yield should be made on the basis of such of the characters as are least affected by environmental conditions, and secondly, when selection is based on several characters simultaneously, the degree of correlation between pairs of different characters should also be considered. Finally, the theoretical weights attached to the different characters used simultaneously in selection should be such that the observed value of a plant or a progeny is highly correlated with its genetic value.

In the past, ratios such as the migration coefficients [grain : total produce, Beaven, 1920] or the survival rate of tillers [Bell, 1937 ; Hunter, 1938] were used as selection indices for evaluating the yielding potentialities of different varieties or lines, but these ratios are of an arbitrary nature, and do not reflect any correlation between the characters and the yield. What we want is to find out a method of selection which would give maximum weightage to (a) those component characters which are least affected by environmental conditions and (b) those characters which show least mutual correlations.

The discriminant function [Fisher, 1936] provides exactly such a method in which both these factors are taken into account. In the linear formula consisting of these characters on which selection is to be based, the relative weights of the observed values of the different characters are so fixed that the resulting compound score is most highly correlated with the genetic value of a variety or line.

The expected genetic improvement for any given selection intensity has always been found to be greater when selection is done with the help of discriminant function than when it is done directly on the observed characters. This is what should be expected, as this function is more highly correlated with the genetic value of the variety or line than any other formula devised for the purpose of selection. The application of the method for plant selection has been developed by Smith [1937] who illustrates its use on wheat. The object of the present study is to work out a discriminant function in relation to selection for high yield in Central India *durum* wheats.

The theory of the discriminant function

If a variety or line of wheat is measured in η characters say χ_1 $\chi_2 \ldots x_n$, then the genotopic yield value of the variety ψ (psa·) can be scored as

$$\psi = a_1 z_1 + a_2 z_2 \ldots\ldots\ldots a_n z_n \ldots\ldots\ldots (I)$$

when $+ai$ is the value of x to be expected due to genotype and $a_1 a_2 \ldots\ldots a_n$ are the relative weights attached to these characters.

* Part of the thesis submitted to the Nagpur University for the degree of Master of Science in Agriculture (1944).

Since the genotypes cannot be measured or observed, this genotypic yield value of the variety can only be estimated from the mean values of the different characters of the progenies, and these observed values are affected by environment and may also be mutually correlated. On account of these factors, the phenotypes have to be scored according to the equation—

$$Y = b_1x_1 + b_2x_2 \ldots\ldots\ldots\ldots\ldots b_nx_n \ldots\ldots\ldots (11)$$

in which, with the help of discriminant function technique, the coefficients $b_1 \ldots b_n$ are so evaluated that the compound score ψ is most highly correlated with μ, the true genetic yield value of the variety or line.

The two covariance matrices necessary for setting up simultaneous equations to evaluate the coefficients $b_1 \ldots\ldots b_n$ are obtained from the mean squares and mean products of varieties or lines and of error for different characters measured in replicated field tests. The details of the calculations are fully described by Smith [1937].

Smith [1937] has also given the expectation of genetic advance by selection with the help of discriminant function over the mean of the original population as $Z/Q\ BV^{\frac{1}{2}}$ when Z and Q are determined by the degree of selection applied, Q representing the intensity of selection and Z, the ordinate of the unit normal curve at the deviate determined by the selection intensity. Once this intensity is fixed, the value of Z can be obtained from a table of normal probability integral. B is the coefficient of regression of the true genetic value on the compound score used for selection and V is the variance of the score between the progenies.

Experimental material

In order to work out a discriminant function for selection in *durum* wheats, sixteen one pound samples of local and improved strains of *durum* wheats, listed in Table I were obtained from Indian States and British Provinces in 1941. The samples were grown along with two of the Institute *durum* wheats, namely Rewa 42 and Dhar Selection, in five randomized blocks on the 29th October, 1941. The size of the plot was 7 ft. × 25 ft. and block size 63 ft. × 50 ft., plots being arranged in two rows in each block. Sowing was done as usual at the rate of 50 lb. per acre. When the germination was complete, a count of plants germinated was taken in four experimental lines, leaving one line on either side and two feet at each end of the plot as non-experimental margins.

Table I

List of durum *wheats worked with*

Name of place	Name of strain	Name of place	Name of strain
1. Bengal	Gangajali 50	10. Hyderabad (Deccan)	Parbhani 1
2. Ditto	Gaithi 29	Ditto	Ditto 2
3. Bombay	Niphad 81	11. Ditto	Ditto 2
4. Ditto	Bansi 168	12. Ditto	Ditto 3
5. Ditto	Bansi 224	13. Ditto	Ditto 4
6. Ditto	Bansipilli 808	14. Ditto	Ditto 6
7. Central Provinces	Bansi local ..	15. Ditto	Ditto 7
8. Institute of Plant Industry	Rewa 42	16. Ditto	Ditto 8
9. Ditto	Dhar Selection ..	17. Ditto	Local
		18. Ditto	Bansi local

From each plot, after thinning out the plants wherever they were in bunches and leaving only singles, twenty plants were selected at random for observations which were then properly labelled for further studies. There were in all 100 plants for each sample. When the crop was ready for harvest which was in the first week of March 1942, the labelled plants were first harvested individually. Mean number of tillers and ears per plant, mean number of grains per ear, and mean weight of 100 grains, besides mean weight of grain and straw per plant were recorded and analyzed statistically.

Results

Statistical analysis of the observations recorded on each sample for each character was done, and the variances and covariances are given in Tables II and III respectively.

Table II

Analysis of variance of the mean number of tillers and ears per plant, number of grains per ear, weight of 100 grains and weight of grain and straw per plant of Provincial durums

Due to	d.f.	Mean number of tillers per plant		Mean number of ears per plant		Number of grains per ear		Mean weight of 100 grains in gm.		Mean weight of grains per plant in gm.		Mean weight of straw per plant in gm.	
		M. S.	V. R.	M. S.	V. R.	M. S.	V. R.	M. S.	V. R.	M. S.	V. R.	M. S.	V. R.
Varieties	17	1·2679	4·18**	1·1372	8·29**	40·1953	2·84**	1·2696	8·19**	1.2311	2·93**	3·6296	2·75**
Error	68	0·3032	..	0·1371	..	14·1096	..	0·1549	..	0·4180	..	1·3180	..

Mean Squares and variance ratios

**Significant at 1 per cent level. $n_1=12$ and $n_2=70$ P=2.45 at 1 per cent

Differences between the varieties for mean number of tillers and ears per plant, number of grains per ear, weight of 100 grains and mean weight of grain and straw per plant are highly significant indicating that the varieties are distinctly different in all characters. These differences are of very high order for mean number of ears per plant and weight of 100 grains.

Correlation coefficients were determined between pairs of different characters for varieties and also for Error (Table III). The correlation coefficients for varieties are positive and significant between number of total tillers at harvest and number of ears, between number of tillers and weight of straw at 1 and 5 per cent respectively. This is to be expected as number of ears and weight of straw are both dependent upon the number of tillers produced. Between number of tillers and number of grains per ear the coefficient is negative and significant at 5 per cent indicating that varieties with high tiller number have fewer grains per ear. The number of tillers is positively correlated with the weight of 100 grains but the coeficient is small and non-significant. The correlation between the number of ears and the numbers of grains per ear is negative and significant at 5 per cent. This is to be expected on account of positive and significant correlation between the number of tillers and the number of ears per plant mentioned above. Between the number of ears and the weight of straw the correlation is significant and positive, between the number of ears and the weight of 100 grains it is positive and non-significant. There is no significant correlation between the number of grains per ear and the weight of 100 grains. Between the number of grains per ear and the weight of straw the correlation is negative and non-significant. The weight of 100 grains has no significant correlation with the weight of straw.

The correlation coefficients between pairs of different characters in the Error line of the analysis are of the same signs as for varieties, except between the number of tillers and the weight of 100 grains, between the number of ears and the number of grains per ear and between the number of grains per ear and the weight of straw, but the last alone is significant.

Correlation coefficients between the number of tillers and the weight of 100 grains are non-significant and of a very small magnitude both for the varieties and for error. The correlation between the number of ears and the number of grains per ear is negative and significant for varieties, but positive and non-significant for error. Between the number of grains per ear and the weight of straw the correlation coefficients both for varieties and for error are of the same magnitude, but for varieties the coefficient is negative and non-significant. When the correlation between the varieties differs from the corresponding correlation in error part of the analysis, the differences must be interpreted as being due to the difference between genetic associations, that is, those due to linkage or similar causes and physiological relationship. To illustrate the difference, the correlation between the number

TABLE III

Analysis of covariance between the number of tillers and ears per plant, number of grains per ear, weight of 100 grains and straw per plant of Provincial durums

Due to	d.f.	No. of tillers × No. of ears: Mean product	No. of tillers × No. of ears: r	No. of tillers × No. of grains per ear: Mean product	No. of tillers × No. of grains per ear: r	No. of tillers × Weight of 100 grains in gm.: Mean product	No. of tillers × Weight of 100 grains in gm.: r	No. of tillers × weight of straw in gm.: Mean product	No. of tillers × weight of straw in gm.: r	No. of ears × No. of grains per ear: Mean product	No. of ears × No. of grains per ear: r	No. of ears × Weight of 100 grains in gm.: Mean product	No. of ears × Weight of 100 grains in gm.: r	No. of ears × weight of straw in gm.: Mean product	No. of ears × weight of straw in gm.: r
Varieties	17	+1·1109	+·9252**	—3·7297	—·5224*	+·0790	+·0622	+1·1072	+·5161*	—3·7729	—·5580*	+·1165	+·0969	+1·2996	—·63
Error	68	+0·1215	+·5961**	—0·1097	—·0530	—·0126	—·0581	+·2090	+·3306**	+·2249	+·1617	+·0309	+·2120	+·2905	+·683

(Mean products and correlation coefficients)

Due to	d.f.	No. of grains per ear × Weight of 100 grains in gm.: Mean products	No. of grains per ear × Weight of 100 grains in gm.: r	No. of grains per ear × Weight of straw in gm.: Mean product	No. of grains per ear × Weight of straw in gm.: r	Weight of 100 grains in gm. × Weight of straw in gm.: Mean product	Weight of 100 grains in gm. × Weight of straw in gm.: r
Varieties	17	+·7936	+·1110	—3·0763	—·2546	+·9462	+·4497
Error	68	+·0056	+·0037	+1·2115	+·2890*	+·1012	—·2239

$n=16$, $r=·4683$ and ·5897 for 5 per cent and 1 per cent respectively. $n=70$, $r=·2319$ and ·3017 for 5 per cent and 1 per cent respectively.

* Significient at 5 per cent level.
** „ at 1 per cent „

of ears per plant and the number of grains per ear may be quoted. Between varieties, there is a significant negative correlation between the two characters showing that the varieties with a large number of ears per plant have fewer grains per ear, but the error correlation is positive and non-significant showing that the relationship between the characters is not of a physiological nature, and we consequently expect to obtain plants with a large number of ears also having a large number of grains per ear. A similar explanation fits in for the difference between the number of grains per ear and the weight of straw. On the other hand the correlation between the mean number of ears per plant and the weight of straw per plant is positive and of almost the same magnitude both for varieties and for error. This simply means that plants with a large number of ears must also possess a large weight of straw which is to be expected. The same relationship is shown by varieties as well.

Such correlations can give us information only about the simple associations (negative or positive) between pairs of different characters, but only by means of a method like the discriminant function can we take into account the effect of selection in one character on the compensating changes in other characters, and ensure efficient selection for improvement with which we are concerned.

The grain yield of wheat is the product of number of ears per plant $\times$ number of grains per ear $\times$ weight of each grain. When these are transformed into logarithms, the logarithm of yield can be expressed as sum of the logarithms of these components, that is, *log* yield=*log* ear number + *log* grain number+*log* grain weight. This equation enables us to introduce some more characters which though they do not directly contribute to yield of grain may give us additional information on account of their correlation with other characters. The coefficients of such additional characters will be zero, and those of the components of yield as 1. Since antilogarithm of zero is 1, the product of of these components of yield will not change with the introduction of such additional characters.

The number of tillers and ears per plant, the number of grains per ear, the weight of 100 grains and the weight of straw per plant for each of the five blocks were converted into logarithms, and then analysed statistically, and variances and covariances between all pairs of characters were obtained.

We, therefore, take as our variates

x_1 logarithm of mean number of tillers per plant
x_2 ,, ,, ,, ,, ear ,,
x_3 ,, ,, ,, ,, grains per ear
x_5 ,, ,, weight of 100 grains (in gm.)
x_5 ,, ,, ,, ,, straw per plant (in gm.)

Our equation, therefore, for grain yield is

$$\psi = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5$$

Where $a_1 = a_5 = 0$ and $a_2 = a_3 = a_4 = 1$

We, then obtain the values of coefficient b from the following formula,

$$Y = b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$$ as described below :—

The mean squares and mean products in the varietal line of the analysis of variance and covariance termed *tij* are given in Table IV below :

TABLE IV

The mean squares and mean products in the varietal line of analysis of variance and covariance—tij

i	j	Tillers 1	Ears 2	No. of grains per ear 3	Weight of 100 grains in gm. 4	Weight of straw in gm. 5
Tillers	1	0·0219	0·0229	—0·0058	0·0015	0·0156
Ears	2	..	0·0302	—0·0121	0·0004	0·0241
No. of grains per ear	3	..	..	0·0150	0·0018	0·0069
Weight of 100 grains in gm.	4	..	..	..	0·0148	0·0107
Weight of straw in gm.	5	..	..	..	..	0·0472

From each row of Table IV sets of equations are formed similar to the sets of simultaneous equations formed in solving partial regression equations for obtaining **c** values [Fisher 1938]. These values of *c* thus obtained are given in Table V below :

TABLE V

The value of cij.

i	j	Tillers 1	Ears 2	No. of grains per ear 3	Weight of 100 grains in gm. 4	Weight of straw in gm. 5
Tillers	1	380·77	—400·37	—134·09	—64·70	73·64
Ears	2	..	505·30	187·42	89·91	—118·66
No. of grains per ear	3	..	..	149·26	14·04	—32·74
Weight of 100 grains in gm.	4	..	..	..	103·14	—45·85
Weight of straw in gm.	5	..	..	..	..	63·04

The mean squares and mean products for error in the analysis of variance and covariance are termed *cij*. When these are substracted from the corresponding values of *tij* (Table IV), we get the genetic component of mean squares and mean products for the varieties, which are termed *gij* (Table VI).

TABLE VI

The values of gij

i	j	Tillers	Ears	No. of grains per ear	Weight of 100 grains in gm.	Weight of straw in gm.	*A* factors
Tillers	1	0·0166	0·0204	— 0·0048	0·0023	0·0138	0·0179
Ears	2	..	0·0261	— 0·0133	—0·0001	0·0178	0·0127
No. of grains per ear	3	..	..	0·0086	0·0017	—0·0111	0·0030
Weight of 100 grains in gm	4	..	..	..	0·0129	—0·0089	0·0145
Weight of straw in gm.	5	..	..	..	..	0·0274	0·0156

By multiplying *gij* values of each row in Table VI with the corresponding theoretical weights *aj* attached to each character, the values of *A* factors are obtained and are given in the last column of Table VI. For example,

$$A_1 = a_1g_{11} + a_2g_{12} + a_3g_{13} + a_4g_{14} + a_5g_{15}$$
$$= 0\times0\cdot0166 + 1\times00\cdot204 — 1\cdot\times00048 + 1\times0\cdot0023 + 0\times0\cdot0138$$
$$= 0\cdot0227 — 0\cdot0048 = 0\cdot0179$$

Similarly $A_2 = 0\cdot0127$
$A_3 = 0\cdot0030$
$A_4 = 0\cdot0145$
$A_5 = 0\cdot0156$

The values of coefficient *b* are then obtained by multiplying these *A* factors with *cij* (Table V) as follows ; and are given below :

Tillers. $b_1 = A_1c_{11} + A_2c_{12} + A_3c_{13} + A_1c_{14} + A_5c_{15}$
$= 0\cdot0179 \times 380\cdot77 \quad 0\cdot0127 \times 400\cdot37 + 0\cdot0030 \times 134\cdot09 - 0\cdot0145 \times 64\cdot70$
$+ 0\cdot0156 \times 73\cdot64 \quad = +2\cdot3440$

Ears, b_2 $= —1\cdot8589$
Number of grains per ear b_3 $= —0\cdot7749$
Weight of 100 grains (in gm.) b_4 $= +0\cdot7218$

Weight of straw (in gm.) b_5 $= +0{\cdot}2280$

Substituting these values of b in the equation

$Y = b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$

the linear function of the characters x_1 to x_5 is obtained as follows :

$Y = 2{\cdot}3440X_1 - 1{\cdot}8589X_2 - 0{\cdot}7749X_3 + 0{\cdot}7218X_4 + 0{\cdot}2280X_5$ (i)

When samples are scored with the help of this function the values so obtained will be highly correlated with the genotypic values of the samples, and will show the yield potentialities of the various samples.

If the mean number of tillers are omitted from the data as number of tillers and ears are highly correlated, the coefficients of linear function can be recalculated, and are given below :

$Y = 0{\cdot}6058X_2 + 0{\cdot}0506X_3 + 1{\cdot}1201X_4 - 0{\cdot}2253X_5$ (ii)

With the help of these functions, we can now obtain scores for each variety or line by substituting the mean values of characters x_1x_2, x_3, x_4 and x_5, the scores thus obtained will represent the inherent value of the variety or line. In respect of tiller and ear number, weight of 100 grains and weight of straw the scores will be affected roughly in proportion to the magnitude of the coefficients, as mean values of the characters are of the same order, that is, the mean number of tillers ranges from 2·41 to 4·63, the mean number of ears from 1·82 to 3·79, the mean weight of 100 grains from 3·31 to 5·35 gm., and the mean weight of straw from 2·48 to 6·03 gm., but the values of the scores will be influenced to a greater extent than expected from the magnitude of the coefficients of grain number per ear, as the mean of this character which ranges from 17·33 to 28·16 is about seven to eight times the mean of other characters.

It will thus be observed that plants selected with the help of function (i) will improve the yield when the basis of selection is high number of tillers and high grain weight, while high ear number and high grain number per ear will decrease it. If tillers are omitted from consideration, and selection is done with the help of function (ii), then high ear number and high grain weight should be the basis of selection. Selection for high grain number per ear will not show appreciable change as its coefficient is very small.

Genetic advance

By genetic advance we understand improvement achieved through selection, and its magnitude may be estimated by the percentage excess in the mean yield of the progenies of the selected plants over the mean yield of the original unselected material. When the varities are evaluated with regard to their yield potentialities by means of discriminant function which gives for each variety or line a score highly correlated with the genotypic value of the variety or line or by ordinary selection in which the varieties are scored on the basis of observed values of different characters assuming these to be the best expressions of the genotype, the difference between these two procedures of selection may be expressed algebraically as the difference between the following two expressions :

(i) formula for discriminant function, $Y = b_1x_1 + b_2x_2 + \ldots b_nx_n$

(ii) formula for ordinary selection $Y = a_1x_1 + a_2x_2 + \ldots a_nx_n$

Where $x_1x_2 \ldots x_n$ represent in both formulae the mean performance of the progenies for the characters, $b_1b_2 \ldots b_n$ in formula (i) are the coefficients obtained by the discriminant function technique and $a_1a_2 \ldots a_n$ in formula (ii) are the theoretical weights attached to these characters.

The greater efficiency of the discriminant function will be reflected in the greater magnitude of genetic improvement brought about when selection of a given intensity is made with the help of discriminant function instead of being based on the apparent value of the material. This point is discussed below :

The expectation of genetic advance by discriminant function over the mean of original population is shown to be $Z/QBV^{\frac{1}{2}}$ [Smith, 1937], assuming the original population to be normally distributed, when Q represents the fraction of the population selected, and Z the ordinate of the unit normal curve at the deviate determined by the selection intensity, and B is the regression coefficient of the true genetic value ψ on the compound score Y, that is $B = W/V$, where W is the covariance of ψ and Y and V the variance of Y.

When the intensity of selection is fixed, the values of Z and Q are constant, and the expectation of genetic advance is proportional to the quantity $B\sqrt{V}$ which alone need be calculated. Table VII shows this quantity after conversion into original units and the percentages of excess of genetic advance by discriminant function over ordinary selection.

TABLE VII

The quantity $B\sqrt{V}$ after conversion into original units and the percentage of excess of genetic advance by discriminant function over ordinary selection

Characters	Index of genetic advance		Percentage excess of advance by discriminant function
	Discriminant function	Ordinary selection	
All five characters	1·536	1·320	16·4
Four characters (tillers omitted)	1·388	1·320	5·2

In calculating the values of $BV^{\frac{1}{2}}$ for ordinary selection numerical values of a, coefficients are used in place of the value of b, coefficients used in discriminant function.

The greater efficiency of the discriminant function is clearly brought out in Table VII, particularly when all the five characters, namely, tiller number, ear number, number of grains per ear, the weight of 100 grains and the weight of straw are involved. When the tiller number is omitted from the analysis, the discriminant function is superior by about 5 per cent. This difference brings out the importance of tiller number in selection for higher yield. Tiller number is obviously strongly correlated with yield and whereas we can with the help of a discriminant function take this character into account in making selection, we do not utilize this information in adopting the ordinary method of selection.

We may conclude from the experiment on provincial *durums* that selection in *durums* should be done on the basis of high tiller number and high grain weight.

MALVI SELECTIONS

Data from one more experiment which included selections from a local sample of a particular area were analyzed to work out a discriminant function, and is described briefly below :

Seventy-two single ear bulks from a local *durum* wheat were grown with Indore local as a control in a Symmetrical Incomplete Randomised Block experiment in 1940-41 with nine groups. The details of writing out sets and the procedure of analysing the data are given in Fisher [1938], Fisher and Yates [1938.]

The experiment was sown on the 14th October, 1940 and was harvested on the 5th March, 1941. The size of each plot was 14 in. × 11 ft. and the block size 10 ft. 6 in. × 11 ft. One foot at each end of the plot and one row of local wheat on either side of the block were discarded as non-experimental margins. In each plot, after the germination was complete, a count of plants was taken and before the plants started tillering a random foot number was selected and fifteen plants beginning from this mark, which represented about 12 per cent of the average total number of plants per plot, were counted and demarcated by two wooden pegs fixed on either side of the sampling units, for observations like tillers etc. Before the crop was harvested, total number of tillers and ears per sampling unit were counted, and after the harvest, mean number of grains per ear and mean weight of 100 grains were recorded and the data analyzed statistically. The analysis of variance for different characters are given in Table VIII. Differences between the number of tillers and ears per plant, the number of grains per ear and the weight of 100 grains are highly significant indicating that progeny bulks differ among themselves widely in all characters.

TABLE VIII

Analysis of variance for number of tillers and ears per plant, number of grains per ear and the weight of 100 grains of Malvi selections

Due to	d.f.	Mean squares and variance ratios							
		Number of tillers per plant		Number of ears per plant		Number of grains per ear		Weight of 100 grains in gm.	
		M.S	V.R.	M.S.	V.R.	M.S.	V.R.	M.S.	V.R.
Varieties . .	72	63·45	1·68**	49·07	1·40*	5·827	12·64**	0·4283	4·21**
Error . .	512	37·60	..	34·95	..	0·461	..	0·1019	..

** Significant at 1 per cent

* " " 5 " "

$N_1 = 5)$ and $N_2 = 400$ P= 1·38 for 5 per cent.

P= 1·57 for 1 per cent.

The values were then converted into logarithms and variances and covariances between pairs of different characters were obtained. The two covariance matrices of the varietal and error line in the analysis of variance and covariance are given in Tables IX and X respectively.

TABLE IX

The values of tij

i	j	Tillers 1	Ears 2	No. of grains per ear 3	Weight of 100 grains in gm. 4
Tillers	1	0·01397	0·01278	—0·00168	—0·00100
Ears	2	..	0·01291	—0·00134	0·00082
No. of grains per ear	3	..	..	·00688	—0·00055
Weight of 100 grains in gm.	4	..	..	..	0·00368

TABLE X

The value of cij

i	j	Tillers 1	Ears 2	No. of grains per ear 3	Weight of 100 grains in gm. 4
Tillers	1	0·00966	0·00955	0·00079	—0·00004
Ears	2	..	0·01107	0·00098	—0·00026
No. of grains per ear	3	..	..	0·00392	0·00009
Weight of 100 grains in gm.	4	..	..	..	0·00309

The details of the calculations involved in obtaining a discriminant function need not be repeated here as they have been fully described before. The solution of the equations gave the following values of b, the coefficients of the discriminant formula :

Characters	Coefficients	Numerical values
Tillers	b^1	2·2335
Ears	b^2	2·2658
No. of grains per ear	b^3	0·2639
Weight of 100 grains in gm.	b^4	2·0064

The discriminant formula therefore reads:

$$Y = 2{\cdot}2355\ {}_1X - 2{\cdot}2658X_2 + 0{\cdot}2639X_3 + 2{\cdot}0064X_4$$

In this function, the coefficients for number of tillers and weight of 100 grains are positive and high, showing that as these two characters have the highest genetic correlation with yield, selection based on high tiller number and high grain weight will increase the yield of the progenies. The number of ears, as shown before, is negatively correlated with yield. The coefficient for number of grains per ear is positive but has a small value.

The discriminant function formula based on selections within the local sample of Malvi wheat is thus very similar to that derived from the wider variations between *durum* samples from different parts of the country, except for grain number per ear. We may thus formulate the general rule that selection for higher yield in *durum* wheat should primarily be made on the basis of higher number of tillers and higher grain weight.

The expectation of genetic improvement through the use of discriminant function is about 10 per cent over ordinary selection. This means that in samples of low variability also the use of discriminant function is found to be valuable.

Discussion

The primary object of the plant breeder is the production of high yielding varieties. Since yield is composed of number of ears per plant, number of grains per ear and weight of single grain, selection for high yield would mean selection for higher number of ears, higher number of grains per ear and higher grain weight. The breeder, therefore, requires some objective guidance for his selection by which he can exploit the part played by each component in building up the yield.

In the past, various ratios such as the migration coefficient or the survival rate of tillers, were used for judging the yielding capacity of a plant, since such ratios were found to be more stable, that is, had greater freedom from environmental fluctuations than the component characters which are highly affected by environment. But these ratios are of arbitrary nature and are not based on any theoretical considerations. Engledow and Wadham [1923] found that though the migration coefficient appeared to hold some promise as an index of yielding power of single plants, it appeared unsuited to the complete displacement of eye judgment because of the labour it involved. Bell [1937] and Hunter [1938] found high ear survival as the most important index of yield in Barley, but Stephens' results on oats [1942] are in direct variance with Bell and Hunters' conclusions. All these conclusions indicate that these ratios are not sound guides to judge the yielding capacity of plants. The discriminant function method for making selection in plants is more rational as the function not only shows the extent to which each character is genetically related to yield but if the samples are scored by means of this function, the sum total of the linear function of characters gives a value highly correlated with the genotypic yield potentiality of the sample from a given population.

The discriminant function formula for evaluating the yielding power of *durum* wheats are worked out on samples collected from two different sources showing varying amount of variability. These sources are the samples of local and improved strains of *durum* wheat from Bengal, Central Provinces, Hyderabad Deccan, Bombay and Central India States, and the bulk of selected progenies from Malvi local.

The results obtained indicate that a general rule for selection in *durum* wheat cannot be dictated as for such studies a larger number of samples should have been included, but the formulae obtained so far are more or less similar and the results can be stated as follows: (1) discriminant function formula obtained from provincial *durums* shows that tiller number and grain weight have genetic corelation with yield and should only be considered while making selection for high yield, (ii) tiller number and straw weight are highly correlated and to a lesser extent grain weight with yield of bulks of selected progenies from Malvi local. All these formulae therefore stress the importance of tiller number and grain weight as the basis of selection for improving the yield of *durum* wheats. Smith [1937] working with *vulgare* wheats also found that ear number and grain weight were highly correlated with yield.

Since the discriminant function gives values highly correlated with the genetic values of the samples of a given population, the expectation of improvement through discriminant function is always higher than by ordinary selection in which the samples are selected on the basis of their observed values taking them to be the true expression of the genotypic values of these samples, as will be seen from the results of provincial *durums* which show an improvement by selection with the help of discriminant function of about 16 per cent higher than ordinary selection. The efficiency of discriminant function is still higher when used for making selection in samples which show low genetic variability among themselves. For example, in bulks of selected progenies the expectation of improvement is about 10 per cent higher than ordinary selection.

These results illustrate how an objective method of selection can be formulated for improving the yield and other quantities of wheat.

Considering the similarity of conclusions from these trials it can be stated with confidence that selection in *durum* wheats can be based on characters like tiller number and grain weight.

SUMMARY

In order to work out a discriminant function for selection in *durum* wheats, two experiments were laid out, one in 1940-41 and another in 1941-42. The second experiment consisted of samples of local and improved strains collected from Indian States and British India provinces. These were grown in five randomized blocks. Twenty plants selected at random were labelled in each plot for observations which were harvested individually. Observations recorded on random plants were analyzed statistically. The results show that the differences between the varieties for different characters are highly significant. Correlation coefficients were determined between pairs of different characters for varieties and also for error.

The data for each character were converted into logarithms and variances and covariances between all pairs of characters were obtained. With the help of these variances and covariances a discriminant function formula is obtained which shows that tiller number and grain weight are highly correlated with the genetic yield of the varieties, and should be the basis for selection for higher yield in provincial *durums*.

The other experiment (carried out in 1940-41) consisted of seventy-two single ear bulks selected from a local *durum* and compared with local *durum* in a Symmetrical Incomplete Randomized Block layout. Twelve per cent of the average number of plants per plot were sampled out for various observations. These observations were analyzed statistically, and the results indicate high significant differences between the progeny bulks in all characters. The values were converted into logarithms and coefficients of discriminant formula were obtained. This function is similar to the one obtained from Provincial *durum* except for grain number per ear which is high and negative in provincial *durums*.

The expectation of genetic improvement is also calculated in both experiments. In provincial *durums*, if all characters are included, the expected genetic advance is 16 per cent higher than ordinary selection, and when tillers are omitted, it is still higher by 5 per cent. In single ear bulks, the expected genetic advance is about 10 per cent. These percentages stress the efficiency of selection by means of discriminant function.

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STUDIES IN PUNJAB MOTH (*Phaseolus aconitifolius*)

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(With ten text figures)

MOTH (*Phaseolus aconitifolius*) is an important legume of semi-arid regions. Piper [1937] has reported that this crop is a native of India, where it is grown principally as a pulse crop; but large areas are put under it as a forage crop both in the irrigated and *barani* (rain fed) areas of the province; and as such it is usually grown either alone or in mixture with non-legumes like *jowar* (*Sorghum vulgare*) *bajra* (*Pennisetum typhoideum*) *sesamum* (*Sesamum orientale*) and some times with cotton. Its use as a pulse, however, is limited to the south-east Punjab alone.

According to the acreage under crops grown exclusively for forage, collected through the Revenue Department in 1937, *moth* occupied an area of 250,000 acres in the Punjab. This acreage should not in any way be taken to mean that *moth* is a crop of lesser importance as compared to other forage crops, as it is highly drought resistant and is able to produce comparatively high tonnage of green fodder under poor-land conditions with limited supply of irrigation water or scanty rainfall.

Inspite of the fact that the crop has been cultivated in the province for a very long time, there is a great dearth of superior and high yielding varieties. Efforts were, therefore, made to find out some variety or varieties with a view to improving the existing situation.

A large number of investigations on both European and American varieties of field beans have been reported. but up to the present time, none has dealt with the species of *Phaseolus* and the varieties of *Phaseolus aconitifolius* grown for forage or seed. The *moth* bean is grown under a very wide range of climates from the hills of Kangra Valley to the dry tracts of Dera Ghazi Khan. but its chief importance is in the dry tracts. Since the range of climate between these two extremes is very wide, it follows that varieties grown in one part may not always be adapted to the other. The choice of a variety adapted to local conditions affects directly the yield and economic utility of the crop; hence it is absolutely essential that a variety suited to a particular locality should only be selected. However. in order to be able to make this choice, the identity of types and varieties must be established with certainty. It is, therefore, necessary that local *moths* should be classified so that their identity can be established. It is the purpose of this study, (I) to find out a practical basis of classification of field varieties of *moth*; (II) to construct a key based on these characters which are stable under varying climatic conditions; (III) to describe the types grown at the Fodder Research Station, Sirsa; and (IV) to establish one or more types superior to others under the climatic conditions prevailing in the province.

Review of literature

Steinmetz and Arny [1932] reviewed the literature on the subject and stated that Von Martens published his second revised classification of garden beans in 1869, but he made no distinction between garden and field beans. He classified *Phaseolus vulgaris* into seven species according to the shape of seed, and based his secondary division on the colour of the seed.

Irish [1901] described almost all varieties from cultures grown at the Missourie Botanical Garden, on the basis of form and colour of seed, and further used plant and immature pod characters.

It is, however, impractical to use immature pod characters for classification, because pods as such cannot be stored. But seed, pod and type of plant provide a reasonable basis of comparison and identification.

Tracy described American varieties of garden beans in 1907, basing his classification on the habit of the plant and character of green pod. But the distinction will become more apparent if comparison is instituted through the ripe pods. Tracy refers to twelve varieties of field beans.

The description of American varieties by Jarvis [1908] is based on colour, form and size of seed. He grouped varieties according to the type of plant and the character of the pods and refers to 21 varieties.

H

Freeman [1921] described six native field varieties of *Phaseolus vulgaris*, while Hendry [1918] described 16 varieties of field beans adapted to California.

Though classification is of great value to growers and seed producers, its usefulness is very limited.

MATERIALS AND METHODS

It was in the year 1932-33 that a collection of samples of *moth* bean was started. Seed from different *moth* growing areas of the province was secured through the local staff of the Agricultural Department, growers and some Experimental Stations. Efforts were made to obtain seed from all the main *moth* growing areas in the Punjab. The growing of these samples began in 1933 and intensive work with a view to isolate definite types began when the crop was harvested in 1936-37.

To start with *moth* samples were planted in rows 2 ft. apart, but later on were planted 3 ft. apart keeping a distance of about 6 in. from plant to plant in order to study the variants in each sample. Typical and non-typical plants were selected and their seed was grown in progeny rows for observation. The rows showing uniformity and the best performance record were selected and multiplied.

In order to keep the variety pure and to safeguard the effect of crossing, if any, the plants which showed some variation from the selected types were rogued out.

The samples were studied for a period of four years from 1933-34 to 1936-37 at the Fodder Research Station, Sirsa, under irrigation, but under severely hot and dry climatic conditions of the tract.

CLASSIFICATION AND DESCRIPTION

Based on the character of the mature plant

The observations reported herein, are based on the following characters of the full grown plants at the Fodder Research Station, Sirsa :

(i) *Habit of growth.*—In habit of growth *moth* beans may be classified into semi-erect, semi-spreading and spreading, but the range is not very distinct in the mature plants. Usually *moth* has indeterminate habit of growth and as such this character has very limited applicability in classification.

(ii) *Shape of leaves and size of lobes.*—The shape of leaves is a character of utmost importance in *moth*. In the present study the varieties consisted of two main divisions (*a*) broad lobed and (*b*) narrow lobed. The lobes of the former are broad with 3-5 lobes and serrated margins, and those of the latter are palmate having long and narrow finger like lobes. The use of absolute measurements in the description of either broad or narrow lobes, however, appears to be impracticable, because of the wide variations in the size of leaf on a single plant.

(iii) *Time of maturity.*—Time of maturity is of considerable importance, for the length of growing season determines to a great extent the yield of green stuff. It is also of great importance in identifying varieties, which are otherwise similar in their habit of growth and colour of seed. The narrow and broad lobed varieties differ in the time of their maturity—the narrow types ripening approximately one to two weeks earlier than the broad lobed strains.

(iv) *Pod characters.*—Unlike the variation in vegetative parts due to environment, character of the pod is not influenced to any great extent, and is, therefore, more useful in the distinguishing of varieties.

(*a*) *Colour of pod.*—The characteristic colour is developed as soon as the pods approach maturity. Type No. 1 shows straw colour, while No. 2 has smoky colour. Colour in pods is described as it is found to be at the time of maturity.

(*b*) *Length of pod.*—The length of pods has been used by many writers in the description of varieties. Tracy [1907] gives approximate length, breadth and thickness. In the present description length of mature dry pod was measured.

(v) *Dry seed character.*—The mature and dry seeds were used exclusively for classification of the American varieties of beans by Jarvis [1908]. The seeds have invariably been used for the description of varieties by all workers and the descriptions reported are in accord with that practice.

(*a*) *Size.*—The size of dry seeds as reported in this discussion is expressed in two sizes, medium and bold.

(*b*) *Colour.*—Von Martens and others have used the colour of seed for distinguishing varieties. The colour of seed has been recognized by all writers, but Freeman [1921] cited a standard colour chart. *Moth* beans have been arranged in this description into two main groups, namely those with single colour seed coats and those with patterned seed coats. Shaw and Norton [1918] have pointed out that there is no consistent correlation between seed coat colour and colour of flowers; this fact agrees with the findings of this study of *moth* beans.

Summary of characters useful in classification of *moth* beans

The following characters may be used in classifying varieties of *moth* beans :

(*a*) Shape of leaves and size of lobes.

(*b*) Habit of growth of the plant, *viz.*, semi-erect or spreading.

(*c*) Time of maturity.

(*d*) Pod colour and length.

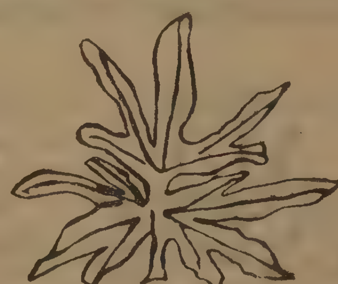
(*e*) Dry seed characters, colour and size of the dry seed.

The present study revealed that the *moth* beans could be broadly classified into two main divisions. In one case the leaves are more or less palmate with long and narrow finger like lobes, while in the other the leaves are much broader with 3-5 lobes and serrated margins.

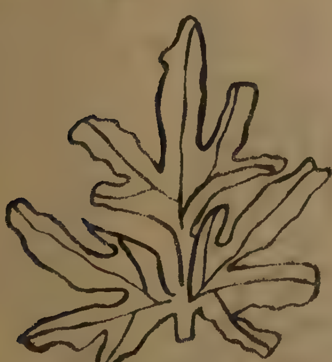
Description of varieties of *moth* beans

Samples of seeds from the various sources were first grown under the name of the place of origin. The names were retained for one year, but as the samples were not true to any known variety description, they were substituted by selection numbers. Later these numbers were replaced by type numbers after the material had been classified and described. The description of the narrow and broad lobed types, shown in figs 1 to 10 is given below :

(1)



(2)



(3)

(4)

(5)

Narrow lobed types

Type No. 1. Plants semi-spreading; leaves dark green, lobes very narrow, central finger of the lobe 3·9 cm. long. ·66 cm. broad; mature pods straw coloured, 4·0 cm. long; seeds per pod 6.6, medium brown, 100 grain weight 1·90 gm.

Type No. 2.—Plants highly spreading; leaves dark green, lobes very narrow, central finger of the lobe 3·8 cm. long., 0·52 cm. broad; mature pods smoky coloured, 3·63 cm. long, seeds per pod 6·9, medium, colour buff with black pattern, 100 grain weight 2·61 gm.

Type No. 3.—Plants semi-errect to semi-spreading; leaves dark green, lobes narrow, central finger of lobe 5·52 cm. long, 1·16 cm. broad; mature pods smoky coloured, 3·73 cm. long, seeds per pod 6·1, medium light brown. 100 grain weight 2·23 gm. Prolific and fairly disease and drought resistant.

Type No. 4.—Plants spreading; leaves dark green, lobes narrow, central finger of the lobe 5·24 cm. long, 1·02 cm. broad; mature pods smoky, 3·63 cm. long, seeds per pod 6·4, medium, greyish brown. 100 grain weight 2·07 gm.

Type No. 5.—Plants spreading; leaves dark green, lobes narrow, central finger of the lobe 4·45 cm. long, 1·1 cm. broad; mature pods smoky, 3·61 cm. long, seeds 6·3 per pod, medium, colour buff with black pattern, 100 grain weight 1·95 gm.

Broad lobed types

Type No. 6.—Plants semi-erect; leaves green, lobes broad, central lobe 4·62 cm. long and 3·28 cm. broad; mature pod straw coloured, 3·77 cm. long, seeds 6·3 per pod, bold brown; 100 grain weight 2·15 gm.

Type No. 7.—Plants semi-erect; leaves green, lobes broad, central lobe 4·9 cm. long, 4·6 broad; mature pod light smoky 4·11 cm. long, seeds per pod 6·2, medium, light brown. 100 grain weight 2·35 gm.

Type No. 8. Plants semi-erect; leaves green, lobes broad, central lobe 4·56 cm. long, 3·1 cm. broad; mature pod smoky, 4·11 cm. long, seeds 7·1 per pod, bold, grey, 100 grain weight 2·15 gm.

(6)

(7)

(8)

(9)

(10)

Type No. 9.—Plants semi-erect; leaves green, lobes broad, central lobe 5·02 cm. long, 3·46 cm. broad; mature pods light smoky, 3·81 cm. long; seeds per pod 6·3, medium, buff with black pattern, 100 grain weight 2·30 gm.

Type No. 10.—Plants semi-erect to semi-spreading; leaves green, central lobe 4·92 cm. long, 4·18 cm. broad; mature pods light smoky, 3·61 cm. long, seeds per pod 5·9, bold, brown, 100 grain weight 2·31 grams.

From a large collection of *moth* samples it was possible to isolate ten distinct types, which have been described above. Each type has been given a number for identification.

Forage yield data have been secured from six promising types out of the ten mentioned above. These data have not been used in the classification, but serve to indicate the value of the varieties under different environmental conditions prevailing in the Punjab.

Along with the study of botanical characters useful for classification, some of the promising types were grown to study their forage value. Since the primary objective of the work was to make available to the cultivators high yielding varieties for forage, results of some of the agronomic studies of six types are reported. To start with, the experiment to compare the forage yielding capacity of these six types was conducted on a field scale at the Fodder Research Station, Sirsa, in randomized plots in 1935-36, and repeated in 1936-37. Later on trials were extended to other Departmental Experimental Stations in order to study their behaviour under different sets of environmental conditions at Montgomery, Hansi, Jullundur, Multan, and Lyallpur under irrigation, and at Rawalpindi and Gurdaspur under *barani* (rain fed) conditions. These trials, which were continued for a period of five years, enabled a detailed study of the influence of variation of environments at different stations within the same year, and at each station in different years.

The sowings at these stations each year were carried out at the usual sowing time, and the crop with a few exceptions made satisfactory growth. The results obtained were very conclusive and enabled a selection of a type, which was approved for cultivation in the Punjab.

The average yields of green fodder per acre, based on the results of these trials at different Agricultural Experimental Stations, are given in Table I.

TABLE I

Yields of green fodder per acre in maunds of the moth *types at the various Agricultural Stations*

1. *Fodder Research Station, Sirsa*

Yield of green fodder per acre in mds.

Year	Types						Local	Significance	Critical difference	
	2	3	4	7	9	10			at 1 per cent	at 5 per cent
1935-36	199	324	304	275	240	..	..	Significant	33	54
1936-37	358	440	377	380	358	299	..	,,	..	67
1937-38	350	458	414	392	384	348	392	,,		
1938-39	342	400	392	368	384	368	322	,,		
1939-40	214	310	292	280	286	290	232	,,		
1940-41	290	360	358	298	284	306	332	,,		
1941-42	233	333	319	321	321	327	288	,,		
Total	1,753	2,625	2,476	2,214	2,257	1,938	1,566			
Average	292	375	353	316	322	323	312			
2. *Montgomery Agricultural Station*										
1937-38	230	305	358	286	271	252	274	Significant	24·9	18·5
1938-39	119	179	187	212	170	149	144	,,	40·3	29·9
1939-40	116	226	118	232	134	176	140	,,	48·0	35·0
1940-41	83	188	161	131	102	154	120	,,	33·7	24·8
1941-42	..	225	185	174	169	188	170	,,	23·9	17·5
Total	548	1,123	1,009	1,035	846	919	858			
Average	137	281	252	259	211	229	214			

TABLE I—*contd.*

Yields of green fodder per acre in maunds of the moth *types at the various Agricultural Stations*—contd.

3. Hansi Agricultural Station

Year	Types 2	3	4	7	9	10	Local	Significance	Critical difference at 1 per cent	Critical difference at 5 per cent
1937-38 . .	96	180	150	127	114	111	110	Significant	26·3	19·5
1938-39 . .	254	298	280	292	261	292	271	,,	9·3	6·9
1939-40 . .	..	..	..	..	..	..	..			
1940-41 . .	221	214	230	221	185	179	198	Insignificant	8·2	6·1
1941-42 . .	278	336	285	287	254	309	296			
Total .	849	1,028	945	927	814	891	875			
Average .	212	257	236	232	203	223	219			

4. Agricultural Station, Jullundur

Year	Types 2	3	4	7	9	10	Local	Significance	Critical difference at 1 per cent	Critical difference at 5 per cent
1937-38 . .	71	90	90	113	109	664	94	Significant	33·0	25·0
1938-39 . .	52	85	76	86	67	65	70	,,	32·0	24·0
1939-40 . .	88	107	123	131	138	141	96	,,	8·2	6·1
1940-41 . .	142	151	169	146	155	150	153	Insignificant	10·7	7·8
1941-42 . .	65	80	64	69	..	..	71			
Total . .	418	513	522	545	469	420	484			
Average .	83	102	104	109	117	105	97			

5. Agricultural Station, Multan

Year	Types 2	3	4	7	9	10	Local	Significance	Critical difference at 1 per cent	Critical difference at 5 per cent
1937-38 . .	112	157	135	128	127	113	101	Insignificant		
1938-39 . .	..	..	..	..	..	..	..			
1939-40 . .	..	..	..	..	..	..	..			
1940-41 . .	113	168	151	134	115	139	142			
1941-42 . .	198	249	242	212	204	250	194			
Total .	423	565	528	474	446	502	442			
Average	141	188	176	158	148	161	144			

6. Lyallpur Agricultural Station

Year	Types 2	3	4	7	9	10	Local	Significance	Critical difference at 1 per cent	Critical difference at 5 per cent
1937-38 . .	99	118	117	132	130	105	80	Significant	34·0	25·0

7. Gurdaspur Agricultural Station

Year	Types 2	3	4	7	9	10	Local	Significance	Critical difference at 1 per cent	Critical difference at 5 per cent
1940-41 . .	200	203	215	207	216	209	215	Insignificant	27·5	20·4

8. Rawalpindi Agricultural Station

Year	Types 2	3	4	7	9	10	Local	Significance	Critical difference at 1 per cent	Critical difference at 5 per cent
1938-39 . .	62	83	68	71	63	65	63	Significant		
1939-40 . .	71	93	81	102	84	83	66	Insignificant		
1940-41 . .	61	61	79	74	68	67	61	Significant		
1941-42 . .	102	126	117	103	95	105	106	Insignificant		
Total .	296	363	345	350	310	320	296			
Average .	74	91	86	87	77	80	74			

Discussion

Yields of green fodder per acre of the six types 2, 3, 4, 7, 9 and 10 were fairly satisfactory at the Fodder Research Station, Sirsa, under irrigation throughout the period of seven years, and significant differences were observed in the performance of these varieties. Taking the data year by year, it is apparent that Type No. 3, with narrow lobes and brown seeds, out-yielded all other types throughout the period of the experiment, and yielded, on an average of seven years, 375 maunds of green fodder per acre. Type No. 4, another narrow lobed type with brown seed, was the second best, yielding on the average, over the same period, 353 maunds of green fodder per acre.

The performance of these types at the Montgomery Agricultural Station under irrigation was quite satisfactory, and the results of the comparative tests were highly significant throughout. Type Nos. 3, 4 and 7 yielded higher than other types and the local. On the average of five years, Type No. 3 was at the top of the list, giving an outturn of 281 maunds per acre. It was closely followed by Type Nos. 4 and 7 which yielded 259 maunds and 251 maunds of green fodder per acre respectively.

The results of the Hansi Agricultural Station, under irrigation over a period of four years, corroborated those obtained at Sirsa and Montgomery. Type No. 3 out-yielded all others, giving an average outturn of 257 maunds of green fodder per acre. It was followed closely by Type Nos. 4 and 7, which gave 236 and 232 maunds of green fodder per acre respectively.

On the average of five years, the yield of green fodder of all the types, except Type No. 2, were higher than the local at Jullundur, but differences among them were not marked. Type No. 9, a broad lobed type, gave the highest yield, followed closely by Type No. 7 and others. It may be inferred that no variety of *moth* is likely to give very high yields, Jullundur being situated in that part of the Punjab, where there is comparatively high rainfall and high humidity, a climate which is not very suitable for this crop.

Yields at the Multan Agricultural Station are not very encouraging; but keeping in view the nature of the soil, which is mostly alkaline, and limited availability of irrigation water, because irrigation is carried on by wells (now farm area has been irrigated through a canal), and very low rainfall and low humidity, outturns of green fodder appear fairly satisfactory. On the average of three years (as trials could not be arranged for the two years, 1938-40), Type No. 3 has out-yielded all other types and the local by a fairly wide margin; Type No. 4 is a close second yielding 176 maunds per acre.

The test was conducted for one year at the Lyallpur Agricultural Station, and during that year only Type No. 7 significantly out-yielded the local. The yields on the whole were very low as the experiment was conducted on a very light soil.

Gurdaspur, which represents another humid tract of the Punjab, is also not very suitable for the growth of the *moth* crop. Here yields obtained from various types and the local were almost equal.

Comparative trials of *moth* types at the Rawalpindi Agricultural Station under *barani* conditions can hardly be expected to give very high yields of green fodder. The results of four years' experiments at this station showed the superiority of Type No. 3, followed closely by Type Nos. 4 and 7.

The results of the above trials, carried out for a period of about half a dozen years, show fairly conclusively the superiority of Type No. 3 over the local as well as other types with which it was compared. The yields have been fluctuating from year to year at the same station and were markedly at variance at the different stations within the same year. It is evident that environmental conditions vary from year to year at the same station, and from one station to another, which is shown by the yields of Type No. 3 (Table II, *see* next page) during these years at the same station in different years, as well as at different stations during the same year.

Often conclusions from varietal experiments, based on the results of a single season, are likely to be highly misleading. Data, which are obtained from a wide range of ecological conditions obtaining from year to year at the different stations, and in different years at the same station, show conclusively that Type No. 3 is a variety which can do better than other types in the arid areas of the Punjab. Accordingly it was recommended and placed on the list of approved seeds of the

Department of Agriculture, Punjab. Type Nos. 4 and 7 follow Type No. 3 closely, but further breeding work on the crop is likely to yield much superior strains than these types and Type No. 3.

TABLE II

Yields of green fodder per acre of Type No. 3 in maunds

Year	Stations							
	Montgomery	Sirsa	Hansi	Jullundur	Multan	Lyallpur	Gurdaspur	Rawal-pindi
1935-36 . . .	..	324	..	..	..	..	..	..
1936-37 . . .	..	440	..	..	..	..	..	..
1937-38 . . .	305	458	180	90	157	118	..	..
1938-39 . . .	179	400	298	85	..	..	..	83
1939-40 . . .	226	310	..	107	..	..	..	93
1940-41 . . .	188	360	214	151	168	..	203	61
1941-42 . . .	225	333	336	80	240	..	..	126

SUMMARY

(1) A large collection of *moth* samples was studied for a period of four years, and on the basis of the stable characters, the material was classified.

(2) The Punjab *moth* can broadly be classified into two main divisions, *viz.* narrow lobed and broad lobed.

(3) In all ten distinct types were isolated on the basis of the habit of the plant, size of lobe, colour of mature pod, length of the pod, and colour and size of the seed.

(4) Out of the narrow and broad lobed ten types, six of which appeared promising for forage, were selected and grown at the Fodder Research Station, Sirsa, and later on at other Agricultural Experiments Stations in order to study the influence of varying environments on the fodder yielding capacity of each type.

(5) The yields of green fodder, obtained at Sirsa and other stations, showed conclusively the superiority of No. 3, a narrow lobed type with medium brown seed.

(6) On the basis of its performance, it has been placed on the list of approved seeds of the Department.

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THE ORIENTATION OF THE SEEDS IN SPECIES OF COFFEA LINN. IN MYSORE

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(with plate XVIII)

DURING the investigation of black bean in coffee [Venkatarayan, 1938] certain peculiarities in the orientation of the beans in coffee fruits were noticed. On cutting fruits transversely and examining always the basal half, the appearance of the cleft in the endosperm of the two beans together with their funicles and placentae, is quite characteristic. In a large number of cases it resembles roughly the letter U (Plate XVIII, fig. 3), the two beans being quite symmetrically arranged. The cleft on one side of the fruit is turned left, while the endosperm itself is turned towords the right, and on the other side the cleft is turned right, and the endosperm left. The former may be considered to be a right-handed seed, and the latter left-handed. In some other fruits the appearance of the clefts is like a rounded off Z (Plate XVIII, fig. 1), while in others it is like the letter S (Plate XVIII, fig. 2).In the Z-type since both clefts are turned left, both the seeds are right-handed, and in the S-type, conversely both the seeds are left-handed.

The species of *Coffea* commonly grown in Mysore are *Coffea arabica* Linn., *C. liberica* Hiern. and *C. Laurentii* Wildem. (*C. robusta* L. Linden). *C. arabica* fruits for examination were obtained in 1937 from a private estate, and in 1938, fruits of all the three species on their branches were obtained from the Mysore Government Coffee Experiment Station, Balehonnur. The occurrence of round beans or peaberry in a fruit spoils the count, and hence these were excluded.

Table I shows the results of the examination :

Table I

The distribution of the different types of fruits in Coffea *spp.*

—	U-type		Z-type		S-type		Total three types	Peaberry		Total	
	No.	percentage excluding peaberry	No.	percentage excluding pea berry.	No.	percentage excluding peaberry		No.	percentage of total	Fruits	Twigs
C. arabica—1937 . .	134	51	76	29	54	20	264	40	13	304	12
C. arabica—1938 . .	250	48	115	22	153	30	518	144	22	662	12
C. liberica—1938 . .	134	35	97	25	155	40	386	232	38	618	18
C. robusta—1938 . .	335	37	261	29	305	34	901	312	25	1213	6

It is seen that the U-type arrangement predominates except in *C. liberica*, where owing perhaps to the undue preponderance of peaberry, the-behaviour is anomalous. Of the other two types sometimes one predominates and sometimes the other. In the same cluster in one and the same twig may be found all the three types of arrangement. In all of them the radicle in the seeds is inferior with the micropyle directed downwards and outwards.

Gandrup [1923] in a preliminary count of 11592 beans, mostly of *C. robusta*, found 6156 left-handed and 5436 right-handed or 53·11 per cent left and 46·89 per cent right. In a more detailed examination of a number of berries of *C. robusta* he found U-type berries to vary from 36·84 per cent to 44·79 per cent, while in *C. excelsa* it was 49·68 per cent and in *C. liberica* 44·73 per cent. He had no occasion to examine *C. arabica*. He designates the U-type, antidrom berries, the Z-type, homodrom right, and the S-type, homodrom left. Antidrom is a term used for individuals of the same species displaying right and left hand torsion. In homodrom, the torsion is in the same direction. But variations of the arrangements occur now and then, and it becomes difficult to determine their nature without a careful examination with a lens. Sometimes a secondary fold develops from the endosperm folds and keeps pace with the original fold, thus making it difficult to distinguish between the original and secondary folds. Gandrup [1923] found this variation to occur to the extent of 10 to 18·36 per cent and suggests that this might have some relation to the hybrid nature of such trees. Gandrup [1923] mentions, as a result of a germination study, that the homodrom

left beans have a comparatively poorer percentage of germination than the homodrom right or antidrom beans. No experiments have been conducted here on these lines.

According to Gandrup [1923], Hanausek [1895] working with *C. arabica* did not find as a rule symmetrically developed seeds in the same fruit, but only similarly developed (gleichsinnig) seeds, and only unusually did he find in a fruit a right and a left seed. Gandrup [1923] says that Froehner [1898] found the seeds to develop symmetrically, and also that according to Froehner [1898] there is a possible relation between this and the symmetry in the inflorescence. Gandrup [1923] was not able to confirm this, and suggests that an anatomical study be made to trace any relation between the position of the endosperm folds and the position of the contorted corolla lobes.

Schumann [1891] figures the U-type arrangement for *C. liberica* Bull. Zimmermann [1928], after Marchand, figures the same arrangement for *C. arabica* Linn. Zippel and Thome [1899] figure the U-type arrangement for *C. arabica*. According to Gandrup [1923], von Wettstein in his handbook figures a *liberica* fruit wherein both beans are bent to the right (Z-type or homodrom right) Ukers [1935] after Tschirch and Oesterle, figures the Z-type of arrangement of seeds for *C. arabica*. According to von Faber [1911] the curvature of the ovule is mostly not sympathetic (nicht gleichsinnig) ; by this he means presumably that the berries are of the U-type or symmetrical, but immediately he says that often this is the case, meaning sympathetic or homodrom. This is opposed to Hanausek's view.

The reason for the curvature of the ovule and the presence of the cleft in the endosperm, according to von Faber [1911], is that the locule, at first circular, grows in the tangential direction, becoming radially flattened. Possibly to economize space, the ovule turns close to a side of the locule and when this side is filled up, it bends down the other side. When the locule has reached its definite size and shape, the ovule is forced to bend itself once more to find further space. This it does at the end opposite to the insertion point of the funicle and pushes in between the septum and funicle. von Faber [1911] believes that this growth in length takes place at the distal portion of the endosperm. Gandrup [1923] is, however, of the view that it takes place at the basal portion. This difference of opinion is not of much consequence, since the result is the same. But why in the same plant there should be the three or possibly four different kinds of orientation of the seeds is not clear. Gandrup [1923] was probably right when he connected this with the hybrid character of the plants in the field. The writer's own [Venkatarayan, 1938] deductions in regard to black bean in coffea, point to the conclusion that there are possibly a number of hybrid plants in any estate. But this hypothesis requires experimental confirmation.

Summary

In this paper, the orientation of the seeds in *Coffea arabica* Linn., *C. liberica* Hiern., and *C. Laurentii* Wildem. (*C. robusta* L. Linden) in Mysore is described. If fruits are cut transversely, and the basal half examined (each seed viewed from the ventral side) the appearance of the cleft in the endosperm, the funicles and placentae is characteristic. In the majority of fruits the appearance suggests the letter U, the two seeds being symmetrically arranged. In other fruits, the appearance of the clefts resembles a rounded off Z and in yet others the clefts resemble the letter S. There are also some abnormalities associated with this arrangement.

The U-type fruits are antidrom, the Z-type fruits are homodrom right, and the S-type, homodrom left.

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FIELD-STUDIES ON SUGARCANE BLACK BUG (*MACROPES EXCAVATUS* DIST.) IN THE PUNJAB

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(Received for publication on 21 November 1944*)

Black bug (*Macropes excavatus* Dist.) is one of the destructive pests of sugarcane in the Punjab. According to Rahman and Ram Nath [1939], the first report of its occurrence as a serious pest of sugarcane in the Kangra valley was received in July, 1930; later reports were from Bhalwal (Shahpur District) Gurdaspur, Kabirwala, (Multan district), Lyallpur and Sonepat (Rohtak district). Since then, it has been found to be widely distributed in the districts of Karnal, Ambala, Ludhiana, Jullundar, Hoshiarpur, Ferozepore, Amritsar, Lahore, Gujranwala and Jhang. The nature of damage caused by this pest has been described by Rahman and Dalbir Singh [1943]. During July 1943, *Macropes excavatus* Dist. appeared in an outbreak form at Karnal and the different varieties of sugarcane appeared to have different intensities of attack. The present paper embodies the results of the investigation carried out on its behaviour and population during 1943-44.

Method and material

The sugarcane black bug multiplied in large numbers at the District Agricultural Farm, Karnal during July-August, 1943, in the five varieties of sugarcane, *viz.*, Co.L.5, Co.L.7, Co.312, Co.395 and Co.421, which had been planted in replicated plots. In each variety, population of the pest on every part of the plant was recorded during the second half of August when the pest was found both in the nymphal and adult stages. For population studies, 300-500 canes, taken at random, from each variety, were examined. The insects were found inside all the loosely attached leaf-sheaths and in the top-whorl. By August, every cane shoot had two to ten partially separated leaf-sheaths and almost all of these were harbouring insects. Separate records of the number of insects (both adults and nymphs) found inside all the leaf-sheaths and in the top-whorl of each sugarcane shoot were obtained. Observations on similar lines were also recorded during the fourth week of November, 1943, when the pest was found exclusively in the adult stage and a large number of leaves, up to 21 in certain cases, had dried and separated from the cane stem. These observations were repeated during the last week of April, 1944 when the pest was met with only in the nymphal stage. The leaf-sheaths were then tightly fitting to the main stem and as such most of the insects were found in the top-whorl. Thus observations on the behaviour and population of the pest in the fields were recorded during all the phases of its activity and life-history.

Intensity of attack in different varieties

The data collected on the above lines were statistically analyzed. The susceptibility of the five varieties of sugarcane, under consideration, can be determined in two ways, namely, the percentage of infested shoots and population of black bug per shoot in each variety. The number of black bugs per infested leaf-sheath varied from 1-4, 1-40 and 1-9 during April, August and November respectively. The total population of the insects per infested shoot during April, August and November ranged from 1-21, 1-92 and 1-32 respectively. The percentage of infested cane-shoots and the average population of pest in different varieties, recorded at different times, are given in Table I.

*Subsequently received in a revised form on 8 July 1947

TABLE I

The average population of the pest per shoot

Varieties	April	August	November	Percentage of infested cane. April	August	November
Co.421	5·32	7·46	12·93	99·3	92·6	99·3
Co.L.5	5·17	7·08	12·6	96·3	81·2	100·0
Co.L.7	4·98	5·13	12·8	98·0	70·9	100·0
Co.395	4·35	3·82	8·32	95·6	72·8	93·3
Co.312	5·17	3·45	11·71	99·3	81·9	99·3

It will be observed from Table I that during April when the crop was young and the sugarcane black bug had just resumed activity after wintering, there was hardly any difference in its population in the varieties under consideration, and about the same percentage of shoots was found infested in all the varieties. During August when the pest was most active, it exhibited differential behaviour towards different varieties. The figures in Table I reveal that during August the average population of the pest per cane shoot as well as the percentage of infested shoots, were different in different varieties. Figures are the highest in Co. 421 and Co. L. 5. Next in order stands Co. L. 7 : Co. 395 and Co. 312 happen to be the least infested. During November the pest was rather inactive and all the varieties had about the same percentage of infested shoots and had the same population. It is thus evident that the susceptibility of different varieties to sugarcane black bug can be best judged during August, when the pest is active : during April and November varietal differences are not clearly marked.

Observations were also made to analyze the factors responsible for causing variation in black bug infestation in the five sugarcane varieties under study. As the insects were found located inside leaf-sheaths, detailed particulars of the leaf-sheaths in each variety were recorded. Area of the leaf-sheath and the nature of its connection with the cane stem, were worked out. For this purpose, 3rd*, 7th and 11th leaf-sheaths were selected and in each variety measurements of 150 leaf-sheaths of infested canes selected at random were taken during August and November. For finding out the leaf-sheath area, the bottom and top breadths and lengths of sheath were measured. The distance between the cane stem and the upper end of the sheath determined the 'detachment', the downward length up to which the leaf-sheath had separated from the cane stem was determined by inserting a probing needle. On the basis of data pertaining to leaf-sheath and infestation figures in different varieties, it was concluded that variety having broader and loosely attached (having bigger 'detachment' at the top and extending downwards for a longer distance) leaf-sheaths harboured a larger number of insects and had thus higher infestation as shown in Table II.

TABLE II

Showing direct correlation between broader and loosely attached leaf-sheaths and higher infestion of black bug in different varieties

Variety	Measurements of leaf sheaths A Average area in sq. inches)	B Average top detachment (in inches)	C Average detached length (in inches)	A×B×C
Co.421	28·02	1·065	11·72	349·74
Co.L.5	20·17	1·040	10·75	255·50
Co.L.7	17·05	1·385	9·81	231·65
[illegible]	17·91	1·015	10·51	191·15
[illegible]	17·62	0·835	10·11	148·74

* Numbering of leaf-sheaths starts from bottom of the plant

TABLE III

The average population of insects on different leaf-sheaths along with average percentage of canes having black bugs on different leaf-sheaths

Time of ovservation	Average population of insects on different leaf-sheaths																				S.E.	Significant difference
April . .	Leaf-sheath number	4	3	2	1																	0·132
	Average population	*0·242	0·117	0·068	0·019																0·061	0·312
August . .	Leaf-sheath number	3	2	1	4	5	6	7	8	9	10										0·109	0·312
	Average population	1·376	1·325	1·026	1·023	·381	·165	·057	·019	0·011	·001											0·419
November .	Leaf-sheath number	4	5	7	6	3	8	9	10	11	12	2	13	14	15	16	17	18	1			0·755
	Average population	1·331	1·305	1·248	1·237	1·186	1·82	1·04	·94	·62	·56	·33	·29	·18	·08	·047	·02	·002	·007		0·282	0·985
	Average percentage of canes having black bugs on different leaf-sheaths																					
April . .	Leaf-sheath number	4	3	2	1																4·815	10·493
	Percentage of canes having black bug on these leaf-sheaths	16·86	9·64	3·84	1·46																	14·711
August . .	Leaf-sheath number	3	2	1	4	5	6	7	8	9	10										2·107	6·041
	Percentage of canes having balck bug on these leaf-sheaths	42·24	39·68	32·78	27·86	14·82	8·44	2·78	1·30	0·58	0·14											8·103
November .	Leaf-sheath number	4	5	7	8	6	3	9	10	11	12	2	13	14	15	16	17	18	19	1	2·983	8·404
	Percentage of canes having black bug on these leaf-sheaths	61·39	58·1	57·2	56·1	55·7	54·2	46·2	44·2	30·1	23·1	16·7	13·8	9·23	4·94	2·07	1·10	0·56	·066	·028		11·153

* The figures having a common line below do not exhibit any significant difference between them but are significantly different from others.

TABLE IV

Population of black bug on different parts during different months

Time of observation	Number of black bug inside																			
	1st*	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	Top-whorl.
April . . .	0·023	0·070	0·119	0·244																4·510
August . . .	1·026	1·327	1·376	1·023	0·381	0·165	0·057	0·019	0·010	0·001										2·691
November . .	0·007	0·336	1·186	1·371	1·305	1·237	1·25	1·182	1·040	0·950	0·630	0·567	0·290	0·176	0·088	0·047	0·019	0·009	0·0001	0·000

* 1st to 19th denotes 1st to 19th leaf-sheaths

The population of the pest on an infested shoot was not uniformly distributed inside different leaf-sheaths. Moreover, the relative abundance of the insect inside different leaf-sheaths varied at different times of the season. Actual record of the number of insects found inside every leaf-sheath of 300-500 canes in each variety was maintained during April, August and November and it was observed that the trend was the same in all the varieties. The percentage of infested canes having insects inside differnt leaf-sheaths, along with the average population thereon, recorded at different times of the year, is given in Table III.

It will be observed from the Table III that during April, the population of the pest was maximum inside the 4th leaf-sheath and also a higher percentage of infested shoots had insects inside this particular leaf-sheath. During August, the population of the pest was the highest in the 3rd and the 2nd leaf-sheaths; next in order were the 1st and the 4th. The population decreased from the 4th to the 10th. The order of significance in this respect has been shown in Table III by drawing horizontal lines. The low population of the pest inside the 1st leaf-sheath was low probably due to the fact that this part of the plant was almost in the soil and was smeared with mud and water. During November, however, the population was the highest inside the 4th, 5th, 7th, 6th and 3rd leaf-sheaths. The order of significance during this period also has again been shown by drawing lines in Table III. It was also observed that leaf-sheath having the highest population of insects was the most frequently infested. Thus the 'population' and the 'percentage' have similar trends. The distribution of the pest inside different leaf-sheaths had revealed that, in most cases, the infestation was confined to the 3rd to 6th leaf-sheaths. This point is of practical importance as for recording infestation figures for comparing different varieties of sugarcane, quite accurate data can be collected by examining only the 3rd to 6th leaf-sheaths and lot of time and labour saved.

Migration of the pest

(1) *Seasonal migration*

It was observed that insects had different population densities on different parts during different times of the year. During April, all the infested cane shoots had about 4·5 insects in the top-whorl; during August only about 30 per cent of the infested cane shoots harboured about 2·7 insects in this part, while during November there were no insects in the top-whorl. The population inside different leaf-sheaths was also widely different during different periods of the year as shown in Table IV.

Furthermore, the nymphs and adults seem to have preferences for resting on different parts of a plant. Detailed observations were made on the number of nymphs and adults inside different leaf sheaths during August, when the pest was found both in the adult and nymphal stages. There were more nymphs than the adults inside first leaf-sheath but in subsequent leaf-sheaths the number of nymphs decreased and that of the adults correspondingly increased. However, in the top-whorl, the population of nymphs was many times more than that of adults. Details are shown in Table V.

TABLE V

Average ratio of nymph/adult population on different parts of the cane-shoots in different varieties during August

Part of the plant	Co.L.5	Co.L.7	Co.312	Co.395	Co.421
1st leaf-sheath	6·4	6·64	1·5	5·37	1·9
2nd ,,	3·11	2·96	1·76	2·9	2·26
3rd ,,	1·46	1·16	1·26	1·74	1·37
4th ,,	·92	1·62	·83	1·9	·94
5th ,,	·43	·75	·73	2·28	·4
6th ,,	·68	·21	·17	·88	·67
7th ,,	·18	·08	·24	·36	·41
8th ,,	·02	†	†	†	·26
9th ,,	†	·019	†	†	·019
10th ,,	†	*	*	†	†
Top-whorl	38·5	28·6	42·3	55·7	9·5

* Adults and nymphs both absent
† Adults present but nymphs absent

(*II*) *Daily migration*

During April when the plants are young and the season warms up the insects were observed to change places during different hours of the day. In the morning they were found distributed all over the plant but as the day advanced they migrated upwards and at noon all of them congregated inside the top-whorl. In the evening the insects again migrated back to the lower portions of the plant. Results of several days' observations during April, 1944 are presented in Table VI.

TABLE VI

Distribution of black bug on a plant at different hours

Time of observation	Population of black bugs inside				
	1st leaf-sheath	2nd leaf-sheath	3rd leaf-sheath	4th leaf-sheath	Top whorl
7 A.M.	6	28	38	66	972
8 A.M.	2	11	55	81	1059
9 A.M.	5	12	21	63	1102
10 A.M.	7	17	24	102	1153
11 A.M.	3	15	20	34	1164
12 Noon	0	2	1	4	1278
6-30—7-30 P.M.	25	120	80	35	980

SUMMARY

Sugarcane black bug (*Macropes excavatus* Dist.) is one of the destructive and widely distributed pests of sugarcane in the Punjab. Observations on the behaviour of this pest in five varieties of sugarcane at different stages of crop growth were made during 1943 and 1944. Varietal differences with respect to the incidence of this pest are significant only during August when the pest was most active. The varieties having broader and loosely attached leaf-sheaths were more heavily infested. The pest was not uniformly distributed over the infested shoot : heavy infestation was mostly confined to the third to sixth leaf-sheaths. This point is of practical importance as during active period of the pest quite accurate data on the infestation in different varieties and in plots receiving different treatments, can be collected by examining only these particular leaf-sheaths and lot of time and labour saved. The intensity of population on different parts of a plant fluctuated at different times of the season ; when the plants were young, the insects were observed to change places during different hours of the day.

ACKNOWLEDGMENT

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DAMAGE TO THE WHEAT CROP BY RUST IN RELATION TO VARIETY AND TIME OF SOWING

By R. B. Ekbote and Rao Saheb Dr R. J. Kalamkar, Department of Agriculture, C. P.

(Received for publication on 24 June 1946)

An outbreak of black stem rust, *Puccinia graminis* tritici, in an epidemic form, marked the wheat growing season of the year 1943-44. With a view to assess the damage caused to the standing crop, a survey was undertaken in the affected parts of this province and it was observed that, among other things, the time of sowing and the kind of variety grown, principally determined the extent of loss. This visual observation was verified by actual estimation in an experiment which was laid out at Government Farm, Dindori (Mandla District), primarily to ascertain the effect of frost and was to be rejected as there was no frost in that season.

In the experiment referred to above, seven wheat strains, *viz.*, I.P.52, I.P.101, A013, A049, A068, A090, A115 and a local variety (which from the plant characters was found to be A090, the strain grown on a large scale in the locality), were sown on three different dates, *viz.*, 23-10-43, 8-11-43 and 19-11-43, in six replications. The layout was of the split-plot design, with sowing date as the major treatment, varieties being superimposed. The 144 plots were divided into two equal halves from each of which, 8 lines, 2 ft. long were harvested and bulked. Although, both the weight of the produce so obtained and that of the 1,000 grains therefrom were recorded, the actual loss by rust was calculated from the latter. It is a common knowledge that yield is influenced by a variety of factors amongst which plant population surviving at harvest is the most significant and it is this factor which varies greatly in different sowings. On the other hand kernel weight is not appreciably influenced, within certain limits, by sowing time as will be evident from the figures given in Table I.

Table I

1,000 kernel weight of I.P.52, sown at intervals, at Government Farm, Saugor, 1943-44

Sown on	Weight
6-10-43	33·2 gm.
5-11-43	29·0 ,,
6-11-43	30·3 ,,

The figures of 1,000 grain weights from the 288 sub-plots were statistically analyzed and the results obtained, are summarized in Table II.

Table II

Mean 1,000 grain weight in grammes of different varieties sown at intervals

Sowing time	Varieties								Mean	S.E.
	I. P. 52	I.P. 101	A 013	A 049	A 068	A 090	A 115	Local		
Early	25·13	33·61	35·72	36·75	36·67	31·12	30·22	31·96	34·64	
Normal	20·37	20·40	16·21	14·63	17·40	16·90	18·12	17·80	17·72	0·3649
Late	5·92	10·97	9·56	9·56	8·83	10·27	10·71	10·14	10·22	
Mean	22·41	21·66	20·49	20·31	20·96	19·42	21·68	19·96		
S.E				0·3140						

The association of highest grain weight with early sowing in all varieties is indicative of the least damage by rust, which increased significantly with delayed sowing.

Since grain weight is not constant in all varieties, their comparison based simply on their 1,000 grain weights will not be valid. However, the loss in the weight by delayed sowing, within the self-same variety, would indicate the extent to which it has suffered. This has been calculated and shown in Table III.

TABLE III

Loss in 1,000 grains weight (in grammes) of varieties due to delayed sowing

Variety	Loss in weight between early and normal sowings	Loss in weight between early and late sowings
I.P.52	4·76	16·2
A115	12·10	19·51
I.P.101	13·21	22·64
Local (A090)	14·16	21·82
A090	14·22	20·85
A068	19·27	27·84
A013	19·51	26·16
A049	22·12	27·19

It will be seen that the varieties have sustained a loss to a varying degree. I.P.52 showed the least damage, whereas A068, A013 and A049, were most affected.

SUMMARY

An attempt has been made to indicate the damage caused to the wheat crop by rust in relation to the variety grown and the time of sowing.

It was observed that, among other things, the time of sowing and the kind of variety grown principally determined the extent of loss.

THE EFFECT OF FROST ON DIFFERENT WHEAT VARIETIES SOWN AT INTERVALS

By R. B. Ekbote and Dhannalal, Wheat Research Station, Powarkhera, C. P.

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THE wheat crop in the northern part of this province is subjected to occasional damage by frost. In the year 1928-29, an excellent crop was outright destroyed overnight and although such a widespread and calamitous damage has not occurred since then, sporadic attacks have been reported off and on.

In the absence of facilities for artificial testing, experiments were laid out on different farms to ascertain varietal reaction and the effect of time of sowing on the extent of damage under natural conditions of frost occurrence. In these experiments, seven wheat strains, A013, A049, A068, A090, A115, I.P.52, I.P.101 and a local variety were sown on three different dates, *i.e.*, 19-10-42, 29-10-42 and 17-11-42, in six replications. The layout was of the split-plot pattern.

At the Government Farm, Saugor, one of the stations where the experiment was laid out, there was frost on the 7th, 8th and 9th February, 1943, of mild intensity. As the damage was sporadic, the following sampling method was adopted to estimate the same. Four unit areas, each 4 ft. $\times$ 4 ft., were marked out in the affected portions of each plot and the number of affected and normal ears were counted from each of them. The ears were threshed separately and the weight of produce therefrom was recorded. The effect of frost on yield of grain was determined by calculating the difference in the grain weight of the frosted and an equal number of unaffected ear-heads.

The data thus collected was analyzed statistically and the results obtained are given in Table I and II.

Table I

Mean loss in yield in different sowings lb. per acre

Sowing time	Mean loss	Standard error
Early sowing (19-10-42)	23·18	
Normal sowing (29-10-42)	20·87	3·32
Late sowing (17-11-42)	13·54	

Table II

Mean loss in yield of grain of different varieties in lb. per acre

Variety	Mean loss	Standard error
I.P.101	10·77	
I.P.52	11·87	
A115	16·44	
A090	17·65	2·65
A013	20·13	
A049	21·64	
A068	21·74	
Local	32·52	

It is evident that the effect of time of sowing the crop on the extent of frost damage, is not significant although the figures indicate that the loss was less with delayed sowing.

Varietal reaction is, however, clearly perceptible in the case of the local variety, which suffered most and I.P.101 and I.P.52, which sustained the least damage. Strains A115 and A090, too, did not suffer to the extent to which A013, A049, A068 and the local did, although the differences in the loss of yield between them are not in all cases statistically significant.

Summary

Experiments were carried out to ascertain varietal reaction and the effect of time of sowing on the extent of damage under natural conditions of frost occurrence.

The effect of time of sowing the crop on the extent of frost damage was not significant. Varietal reaction on the other hand was clearly perceptible as between certain varieties experimented with.

RESEARCH NOTE

VERNALIZATION, AN AID IN CROP BREEDING

By R. B. Ekbote, Wheat Research Station, Powarkhera, C. P.

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FROM among the wheat varieties obtained from countries outside India, a few were found to be highly resistant to black rust. The use of these strains as parents for crossing with the local varieties, however, presented difficulty on account of their late earing character. To overcome this handicap, an attempt was made to induce early flowering in them, by means of vernalization. For want of a refrigerator or an electorlux, the treatment was carried out in a wide-mouth thermo-flask. Petri-dishes containing the sprouted seeds were placed in a tiffin-carrier which was inserted in the flask. Sufficient ice was added from the sides and on the top of the tiffin-carrier and the supply of ice was replenished off and on. The temperature inside the flask remained 8° to 10° C. The treatment was carried out for 10 days after which the treated seeds were taken out and sown in earthen pots. The untreated seeds, *i.e.*, the controls, were sown in the field. As a result of the treatment, earing was accelerated by 23, 19 and 3 days in E.144, Ex.30 and *Khapli* (*T. dicoccum*), respectively.

In the following year, *i.e.*, 1943-44, salt was added with ice and the mixture was changed more frequently with the result that the temperature inside the flask could be brought down to about 6° C. The period of treatment could, therefore, be prolonged to 25 days. This time, both the treated and untreated seeds were sown in the pots. The former showed an acceleration over the control by 47 days in the case of Ex.30, 35 in Ex.3, 29 in E.144 and 28 in *Khapli*.

The results were very encouraging and enabled the crossing work being taken up from as early as the last week of December.

Judged by the reaction shown by the foreign wheat varieties tried, vernalization is considered to be a distinct aid in crop breeding work.

REVIEW

The New Genetics in the Soviet Union

By P. S. Hudson and R. H. Richens (Published by Imperial Bureau of Plant Breeding and Genetics, Cambridge, 1946) Price 6s.

THE genetics controversy associated with the name of the Russian agronomist, T. D. Lysenko, has now become well-known and has excited a great deal of interest among the scientific workers all the world over. The history of genetical researches in Russia during the last ten years, or a little over, appears strange to outsiders and much confusion exists in the minds of scientists as to the present position of these researches in that country. Scientific theories are known to transcend geographical boundaries and until the end of the third decade there was, as was to be naturally expected, little difference in the genetical theories held in Russia and those in other countries. But some time in 1935, a new school of genetics arose in Russia under the leadership of Lysenko which put forward certain theories very different from those of other geneticists. This gave rise to a great deal of controversy for sometime : gradually the new school of Lysenko and his colleague Prezent became dominant and came to occupy a very prominent place in the U.S.S.R. as a result of the large amount of official support it received.

Attempts have been made in the past by different authors to analyze the theories of Lysenko's School, but the views expressed by them have often been emotional and, as such, a fair criticism of the theories has not been possible. The name of Lysenko has given rise to some sort of prejudice and the new theories have sometimes been condemned by reviewers as absolutely invalid and unscientific and straightaway rejected, although adequate relevant data were not available to people outside Russia. What was needed was an impartial statement without any prejudice whatsoever which would enable the reader to form a correct idea of the actual position of genetical researches in the U.S.S.R. The authors of the present bulletin, Dr Hudson and Dr Richens, have put before the public a very carefully prepared critical statement and have dealt with the relevant facts impartially. In fact this is the first real attempt to give a detailed objective account of the controversy, based exclusively on Russian publications.

It is pointed out that the ideas of Lysenko's School are based on the philosophy of dialectical materialism and they have been very greatly influenced by the writings of Darwin, Micurin and Burbank.

The bulletin is divided into six chapters, the first one being a short introduction to the subject. The historical and psychological background, against which the new theories have developed, has been discussed in the next two chapters. The authors have done well in prefacing the detailed account of the present position of genetical researches in the U.S.S.R. by a clear exposition of the background, since a knowledge of the latter is very necessary for understanding the modern Russian outlook.

The fourth chapter deals with a summary of a very large volume of experimental results claimed by Lysenko's School as evidence in support of its genetical theories. They have been critically discussed under twelve headings, *viz.*, the genetics of earliness, the prediction of dominance, degeneration of pure lines, rejuvenation, induced mutation, segregation, millardetism, F_1 heterogeneity, reciprocal hybridization and internal genetic variation, mixed inheritance, graft hybridization. With regard to the last one, the authors of the bulletin hold the view that further experiments are necessary for coming to a definite conclusion. They state that in most of the other cases the point is not proved by the evidence put forward, or even if proved, as in a few cases, it is nothing new. Lysenko and his followers have stated that the above results hold good under appropriate environmental conditions, but curiously enough these conditions are not specified by them. There have been objections to acceptance of many of these experimental results on account of defective experimental procedures described. The antipahty of Lysenko's school to statistical analysis, even though most of the evidence is quantitative makes its validity still more doubtful.

The theories put forward by Lysenko and Prezent to explain all genetical facts and their own results are dealt with in the next chapter. The most important of their hypotheses is the theory of

'nutrients'. The authors of the bulletin present a critical analysis of the theories to prove their validity or otherwise. They state that a serious general criticism which applies to all aspects of Lysenko's nutrient theory is that it has never been investigated physiologically. According to them 'Nutrients are invoked to explain every kind of genetical phenomenon, but very seldom is any attempt made to specify what the relevant nutrients are, or what is the mode of their action.'

Lysenko and his followers have advanced arguments against Mendelism and indeed have attempted to overthrow modern genetics. Their criticism has been dealt with in the sixth chapter of the bulletin. Much of the criticism of Mendelism by this School owes its origin to the fact that the former does not conform to dialectical materialism and the recognized authorities, *viz*. Darwin, Micurin, Timirjazev and Burbank. Hudson and Richens discuss these arguments critically and state that many of these are worthless, since the new School attacks genetics of thirty years ago. It appears that Lysenko and Prezent are not familiar with modern genetical theories and, therefore much of the criticism loses its value.

The authors have been quite successful in their attempt to present a detailed and critical account of the very controversial subject. Credit is all the more due to them for remaining impartial while discussing the different theories of the new School and analyzing the merits and defects of the arguments of Lysenko and his followers. The restrained language used and the impartiality shown by the authors will, it is hoped, be of the utmost help in removing the misunderstanding that now exists between the school of Lysenko and that of international genetics, and encourage cooperative work by them which is very necessary for arriving at definite conclusions regarding some of Lysenko's results.

The authors have taken great pains in preparing this well-written treatize which will prove very valuable to all scientific workers.

There is a bibliography of about 300 references and all important statements of authors quoted are given in the original language as well as in English.

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